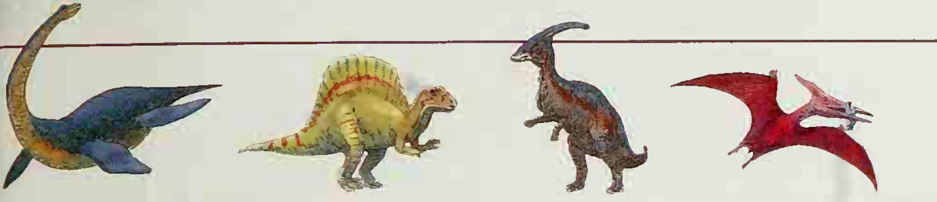
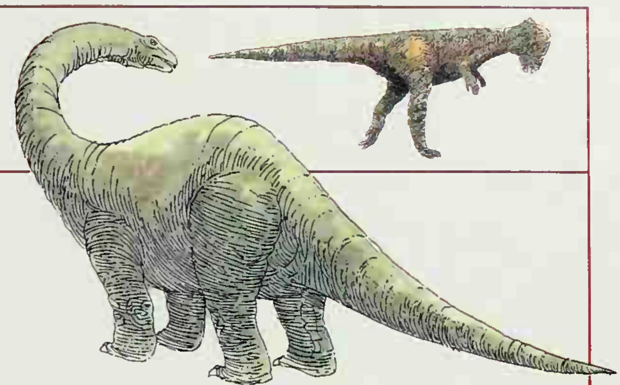
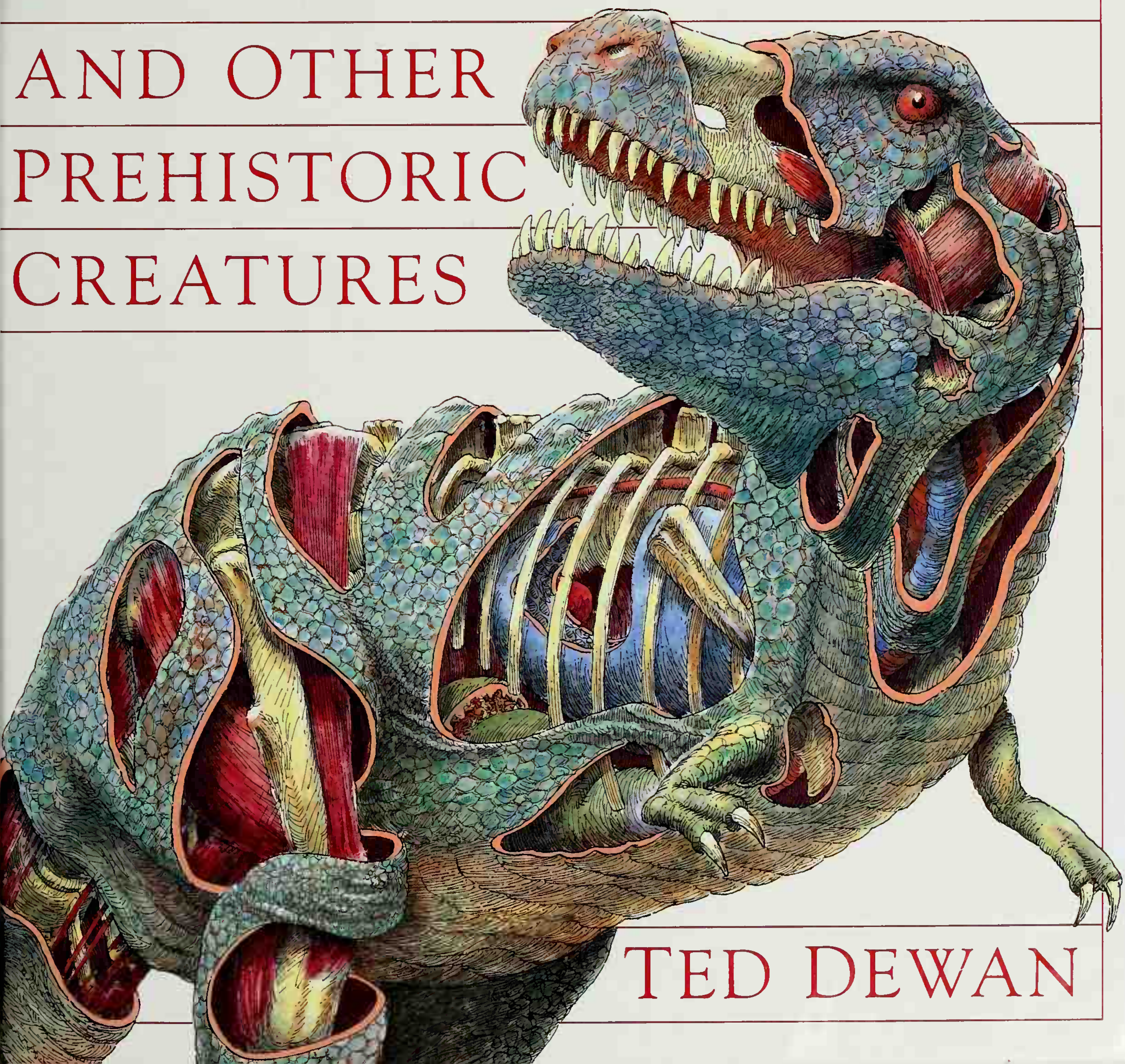



INSIDE DINOSAURS

AND OTHER PREHISTORIC CREATURES

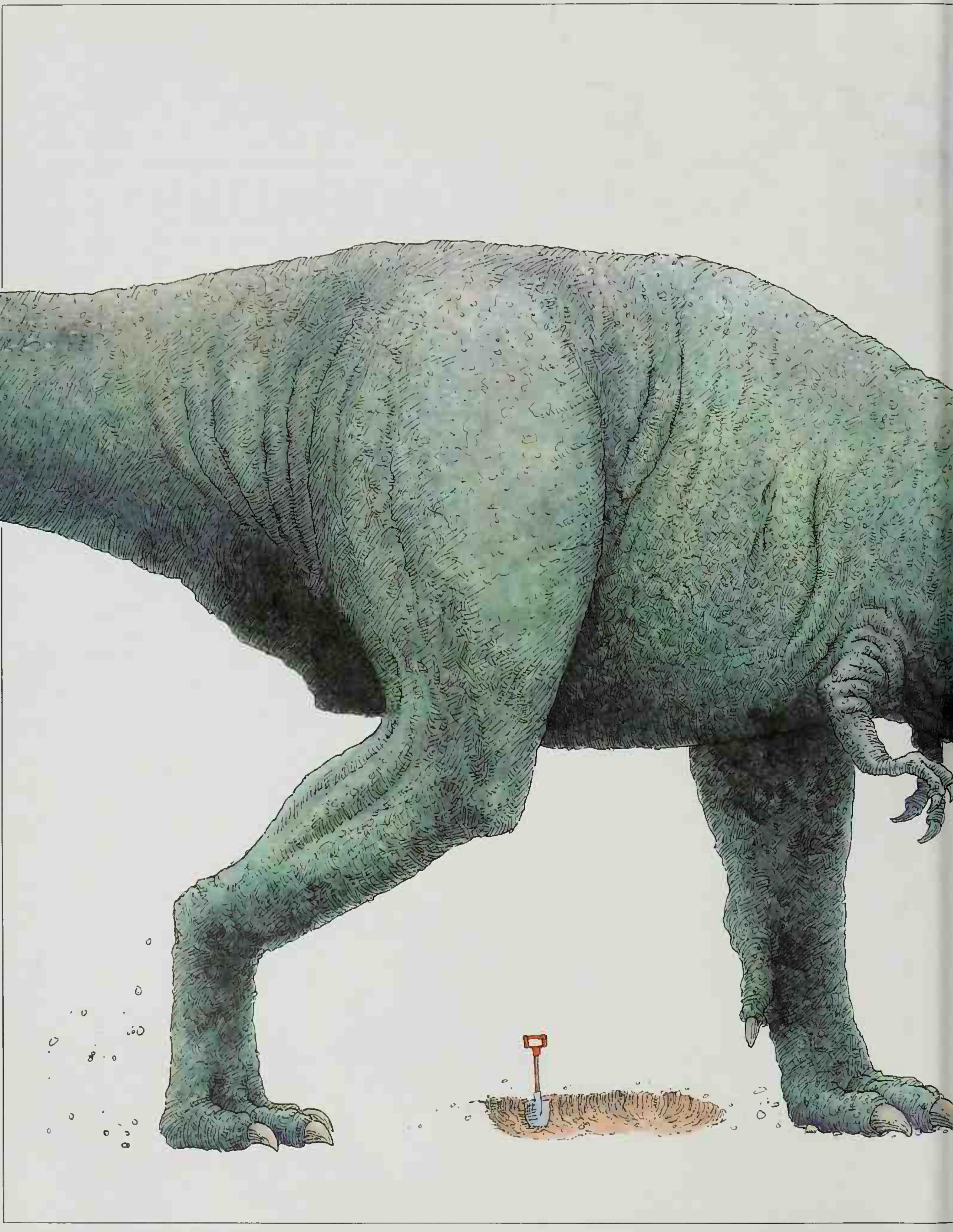


TED DEWAN

INSIDE DINOSAURS

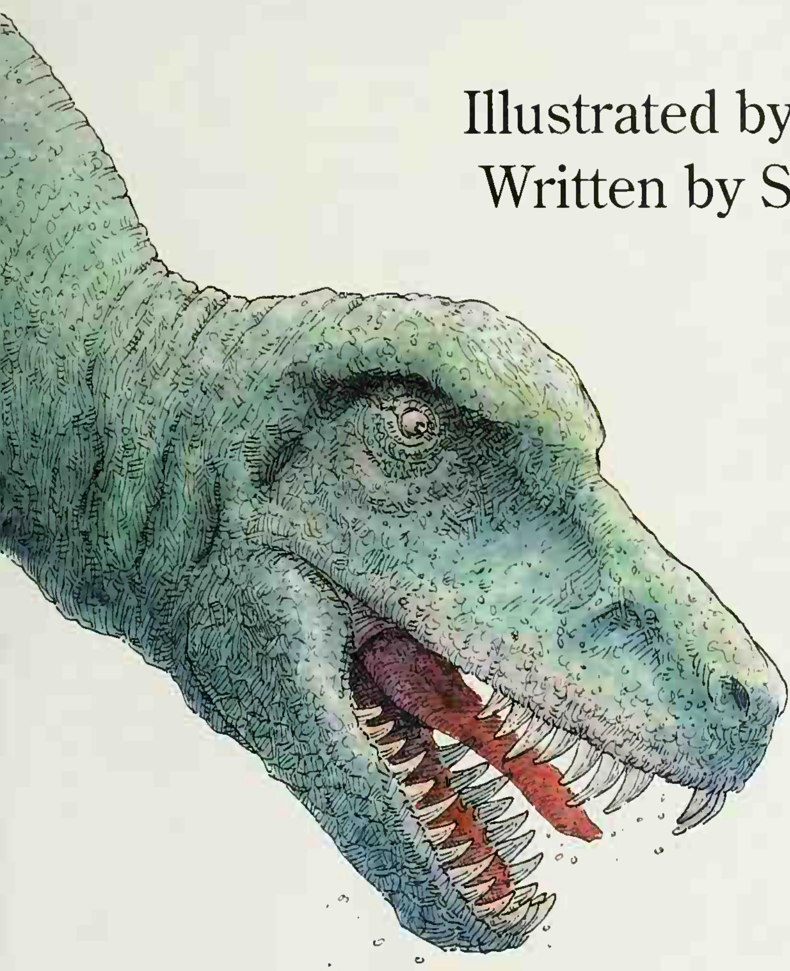
AND OTHER

PREHISTORIC CREATURES



INSIDE DINOSAURS AND OTHER PREHISTORIC CREATURES

Illustrated by Ted Dewan
Written by Steve Parker



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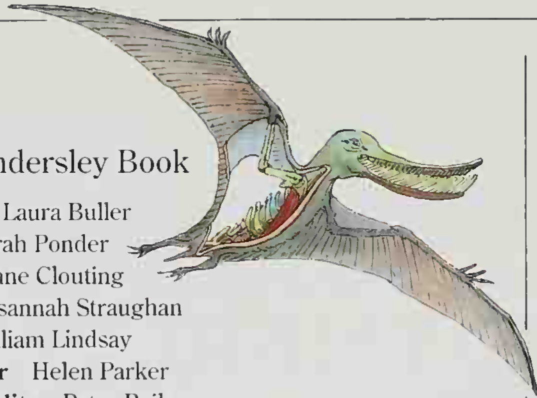

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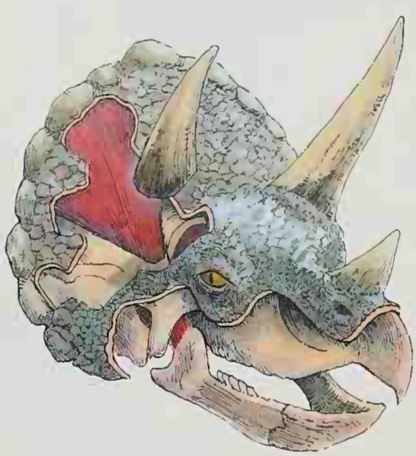
To Gramps—the greatest dinosaur in 64 million years—T.D.

*To the memory of my father, Ron,
who would have been proud—but puzzled!—S.P.*



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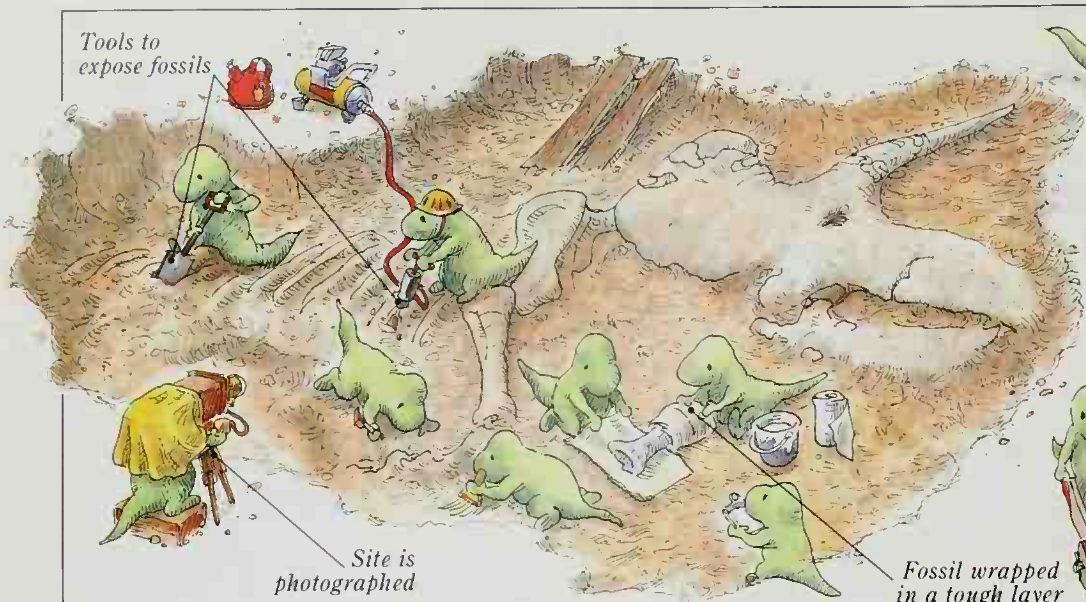
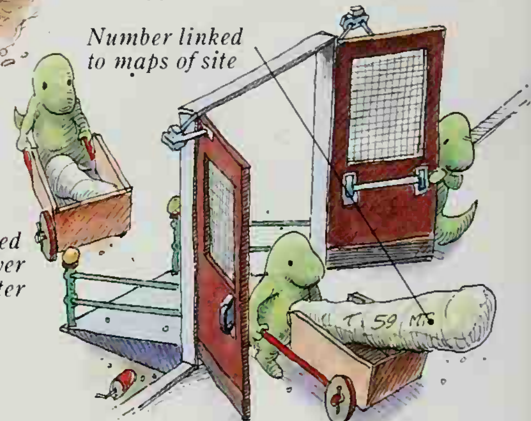


IN THE FIELD
Where do you find a dinosaur? Fossils are found only in sedimentary rocks, laid down in layers on the beds of rivers, lakes, and seas, or in deserts. Rock surrounding the find is carefully cleaned away, while scientists take photos, and make sketches and notes. Some fossils are wrapped in protective plaster jackets.



INTRODUCTION

INSIDE A DINOSAUR? You're kidding! No one ever saw a living, breathing dinosaur—not even a caveperson, since the last dinos died more than sixty million years before the first humans appeared. All that is left of these creatures are bones, teeth, horns, and claws, which turned to stone and formed fossils.

But fossils are valuable clues. For instance, we know from today's animals that flat-topped teeth are for chewing tough plant food. Long, pointy teeth are designed to kill. Straightaway, just one fossil tooth can identify its owner as a plant eater or hunter. Weird and wonderful fossils of dinosaur eggs, last dinners, and dino droppings give further glimpses of their living habits. The remains of other animals and plants found with the fossils, and the rocks surrounding them, tell us about the place a dinosaur called home. Of course, there is still plenty of guesswork. Soft parts, such as brains, hearts, and skin, rarely fossilized. But a little detective work can bring a dino back to life…well, almost.

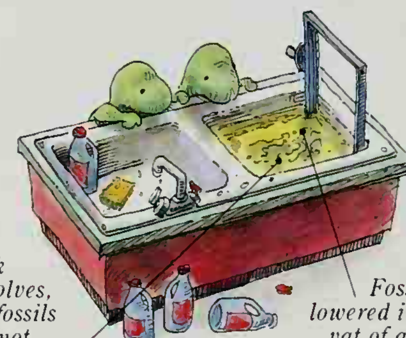
Our previous book, *Inside the Whale and Other Animals*, took animals apart from the outside in. This book puts animals back together, from the inside out. The dinosaurs and other featured creatures that stalked, swam, flew, ran, and lumbered over the planet will give you a peek into the strange and ferocious world that was prehistoric Earth.

Ted Dewan

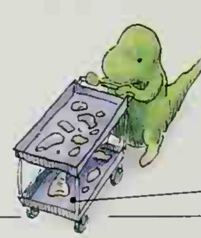
Steve Parker

BACK TO THE LAB
A huge dinosaur fossil is solid rock—so it's very heavy. It may be a long, hard road from a remote fossil site to the comfort of the workshop.

CHECK IN
The fossils are carefully unwrapped and checked. All finds are cataloged and numbered. Your fossil might make headlines, so you'd better not lose it!



EXTRACTING THE FOSSILS
Experts use various methods to clear away the rock around the fossil, including acid baths.



Fill in the blanks

Few fossil skeletons are complete or in perfect condition. It takes a good knowledge of bones, from the living and the long gone, to fill in the missing parts.

Taking shape

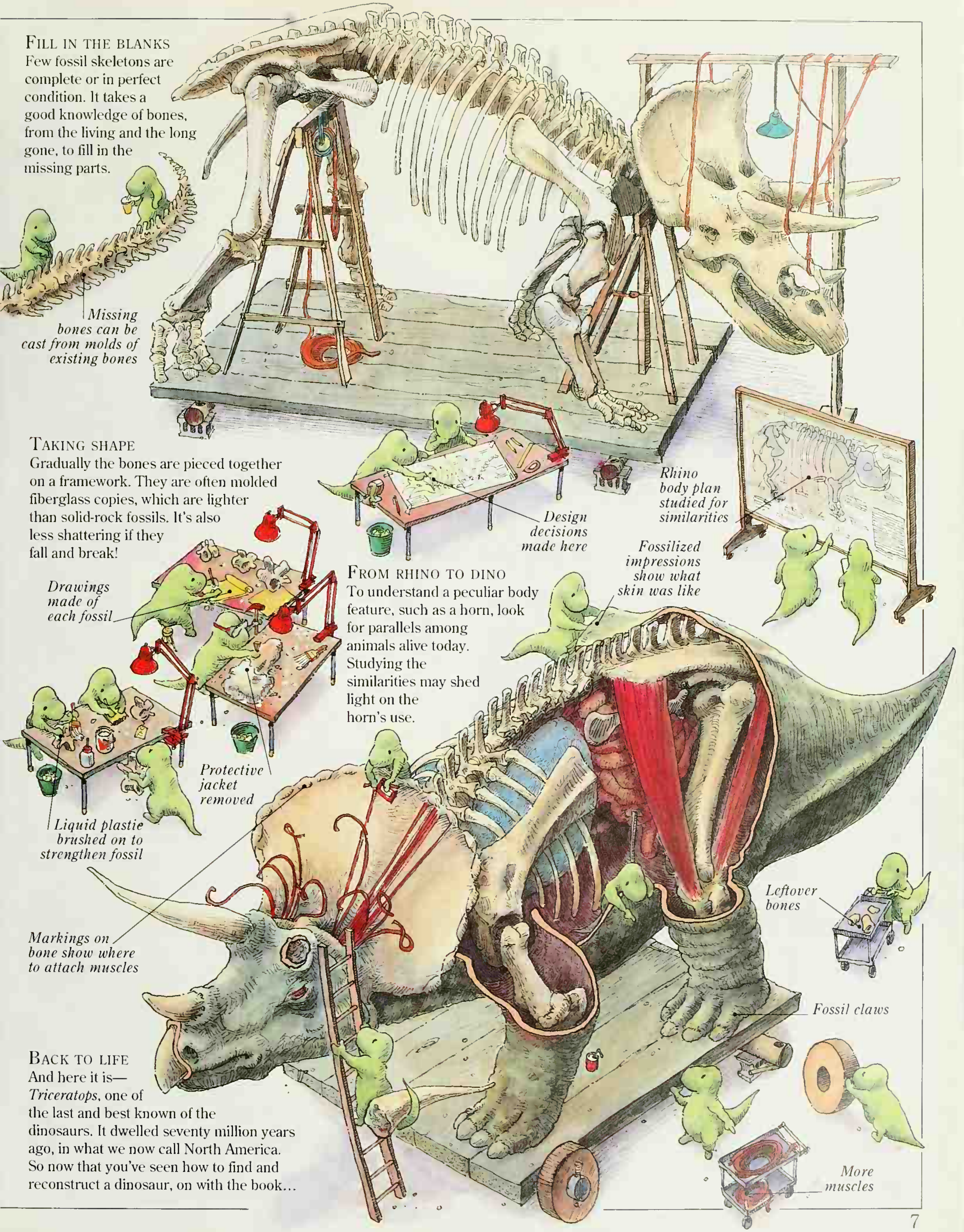
Gradually the bones are pieced together on a framework. They are often molded fiberglass copies, which are lighter than solid-rock fossils. It's also less shattering if they fall and break!

From rhino to dino

To understand a peculiar body feature, such as a horn, look for parallels among animals alive today. Studying the similarities may shed light on the horn's use.

Back to life

And here it is—*Triceratops*, one of the last and best known of the dinosaurs. It dwelled seventy million years ago, in what we now call North America. So now that you've seen how to find and reconstruct a dinosaur, on with the book...

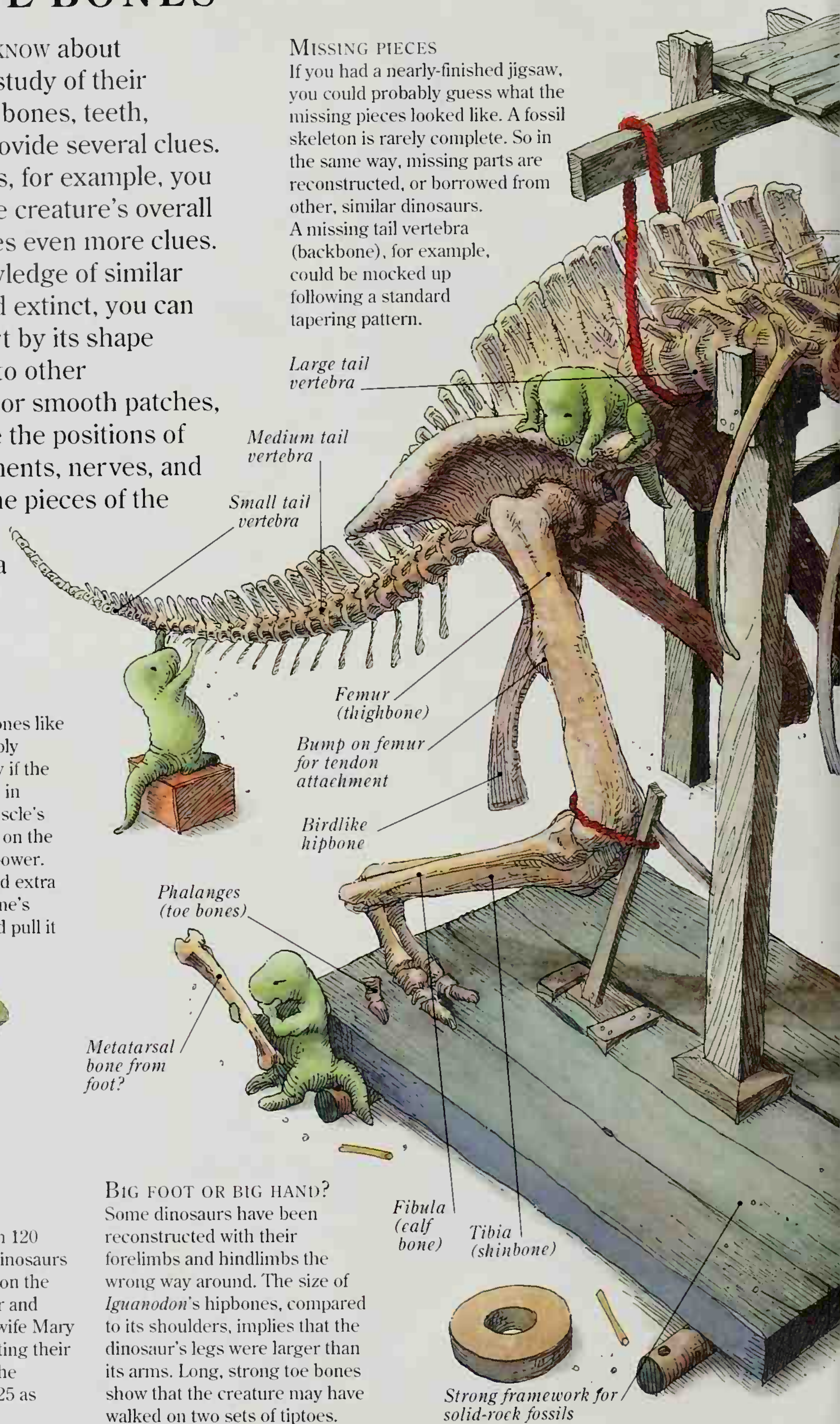


Reading the bones

Most of what we think we know about dinosaurs comes from the study of their preserved remains: chiefly bones, teeth, horns, and claws. These provide several clues. From just a few fossil bones, for example, you can make a good stab at the creature's overall size. The fossil's shape gives even more clues. If you have a working knowledge of similar animal skeletons, living and extinct, you can assign a bone to a body part by its shape alone. Surface details lead to other discoveries. Ridges, rough or smooth patches, holes, and grooves indicate the positions of muscle and tendon attachments, nerves, and blood vessels. Gradually, the pieces of the jigsaw fit together and produce something more: a picture of the dinosaur's behavior and way of life.

Missing pieces

If you had a nearly-finished jigsaw, you could probably guess what the missing pieces looked like. A fossil skeleton is rarely complete. So in the same way, missing parts are reconstructed, or borrowed from other, similar dinosaurs. A missing tail vertebra (backbone), for example, could be mocked up following a standard tapering pattern.



Crests and ridges

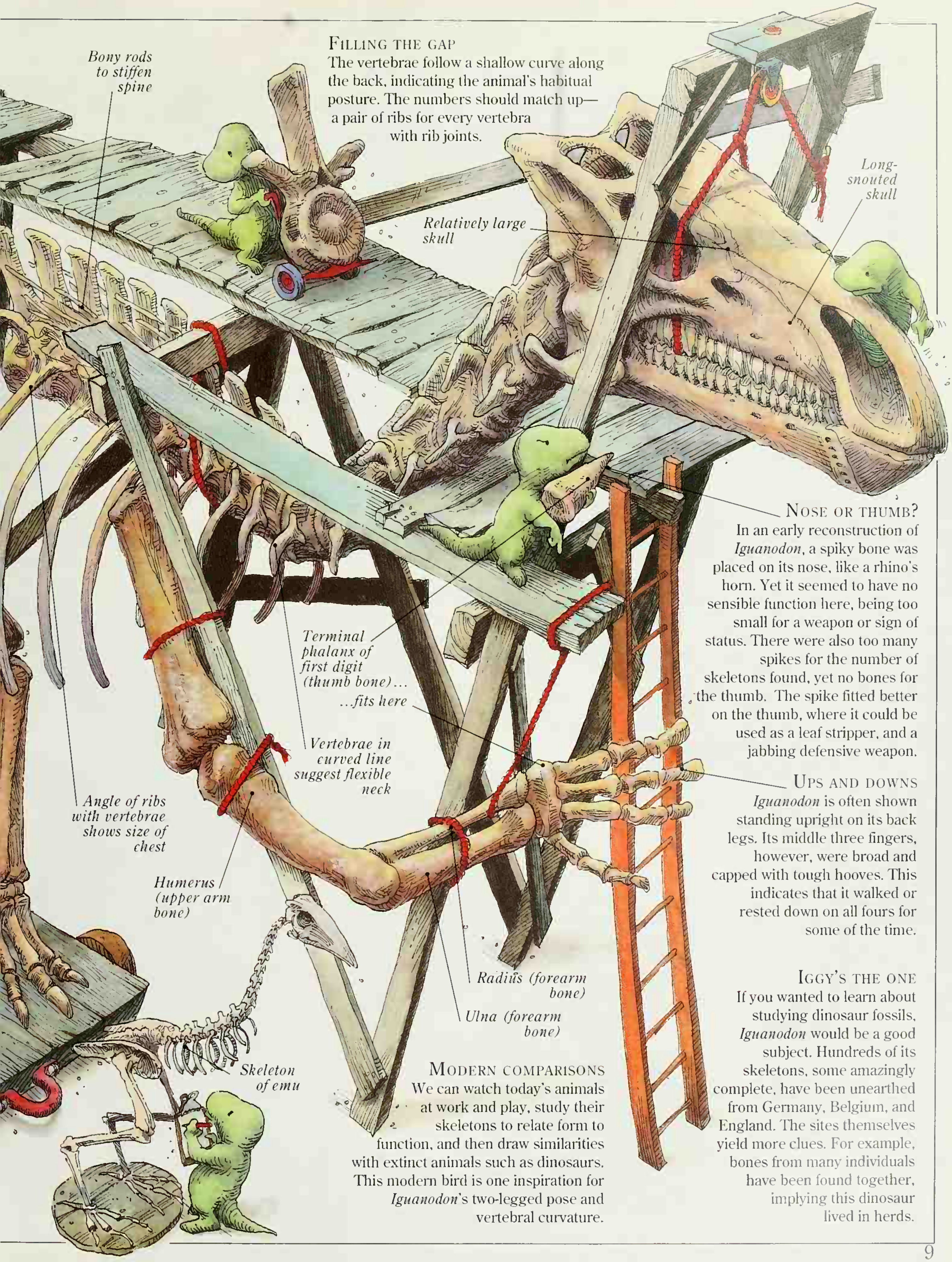
Lumps, crests, and ridges on bones like the bump on this thighbone imply muscle attachments—especially if the surface is roughened and pitted in texture. This was where the muscle's tendon grew into and anchored on the bone, for strength and pulling power. The bumps and flanges provided extra surface area, and angled the bone's surface so that the muscle could pull it more efficiently.

Iguanodon

This 33-foot (10-meter)-long beast from 120 million years ago was one of the first dinosaurs to be officially named and described—on the evidence of teeth alone. English doctor and fossil hunter Gideon Mantell with his wife Mary Ann found the teeth in about 1821. Noting their similarity to those of an iguana lizard, he described the owner of the teeth in 1825 as *Iguanodon* ("iguana tooth").

Big foot or big hand?

Some dinosaurs have been reconstructed with their forelimbs and hindlimbs the wrong way around. The size of *Iguanodon*'s hipbones, compared to its shoulders, implies that the dinosaur's legs were larger than its arms. Long, strong toe bones show that the creature may have walked on two sets of tiptoes.



Filling the gap

The vertebrae follow a shallow curve along the back, indicating the animal's habitual posture. The numbers should match up—a pair of ribs for every vertebra with rib joints.

Nose or thumb?

In an early reconstruction of *Iguanodon*, a spiky bone was placed on its nose, like a rhino's horn. Yet it seemed to have no sensible function here, being too small for a weapon or sign of status. There were also too many spikes for the number of skeletons found, yet no bones for the thumb. The spike fitted better on the thumb, where it could be used as a leaf stripper, and a jabbing defensive weapon.

Ups and downs

Iguanodon is often shown standing upright on its back legs. Its middle three fingers, however, were broad and capped with tough hooves. This indicates that it walked or rested down on all fours for some of the time.

Modern comparisons

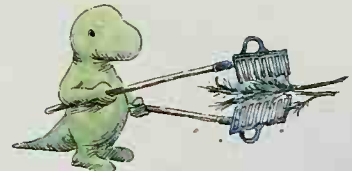
We can watch today's animals at work and play, study their skeletons to relate form to function, and then draw similarities with extinct animals such as dinosaurs. This modern bird is one inspiration for *Iguanodon*'s two-legged pose and vertebral curvature.

Iggy's the one

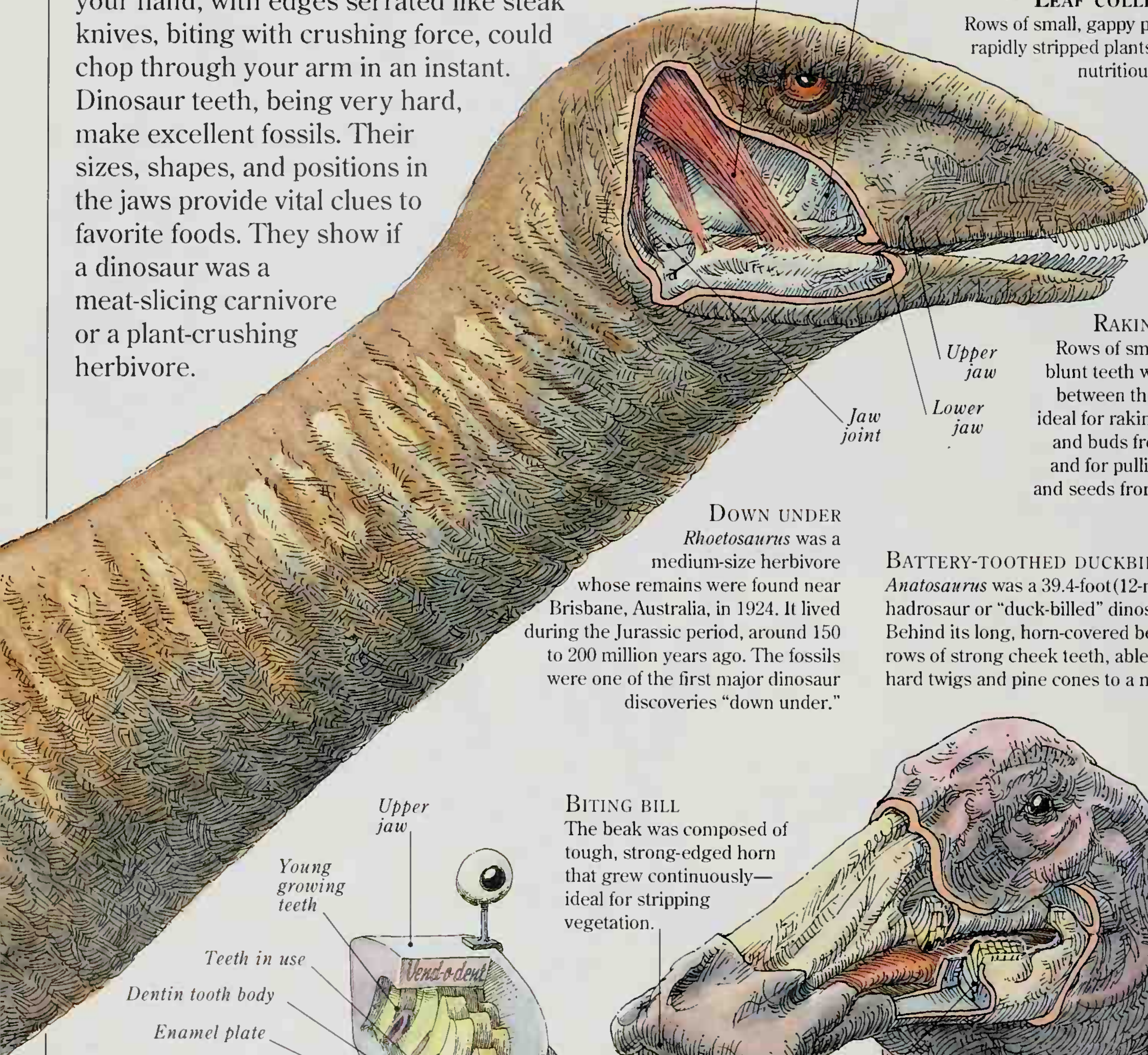
If you wanted to learn about studying dinosaur fossils, *Iguanodon* would be a good subject. Hundreds of its skeletons, some amazingly complete, have been unearthed from Germany, Belgium, and England. The sites themselves yield more clues. For example, bones from many individuals have been found together, implying this dinosaur lived in herds.

TEETH AND JAWS

BEING TRAPPED IN THE TEETH of *Tyrannosaurus* was no joke. Rows of daggers longer than your hand, with edges serrated like steak knives, biting with crushing force, could chop through your arm in an instant. Dinosaur teeth, being very hard, make excellent fossils. Their sizes, shapes, and positions in the jaws provide vital clues to favorite foods. They show if a dinosaur was a meat-slicing carnivore or a plant-crushing herbivore.



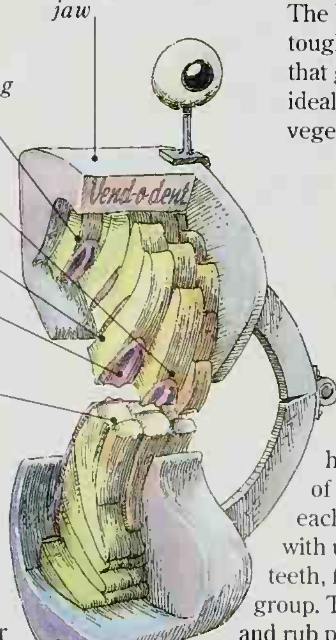
LEAF COLLECTORS
Rows of small, gappy peg teeth rapidly stripped plants of their nutritious leaves.



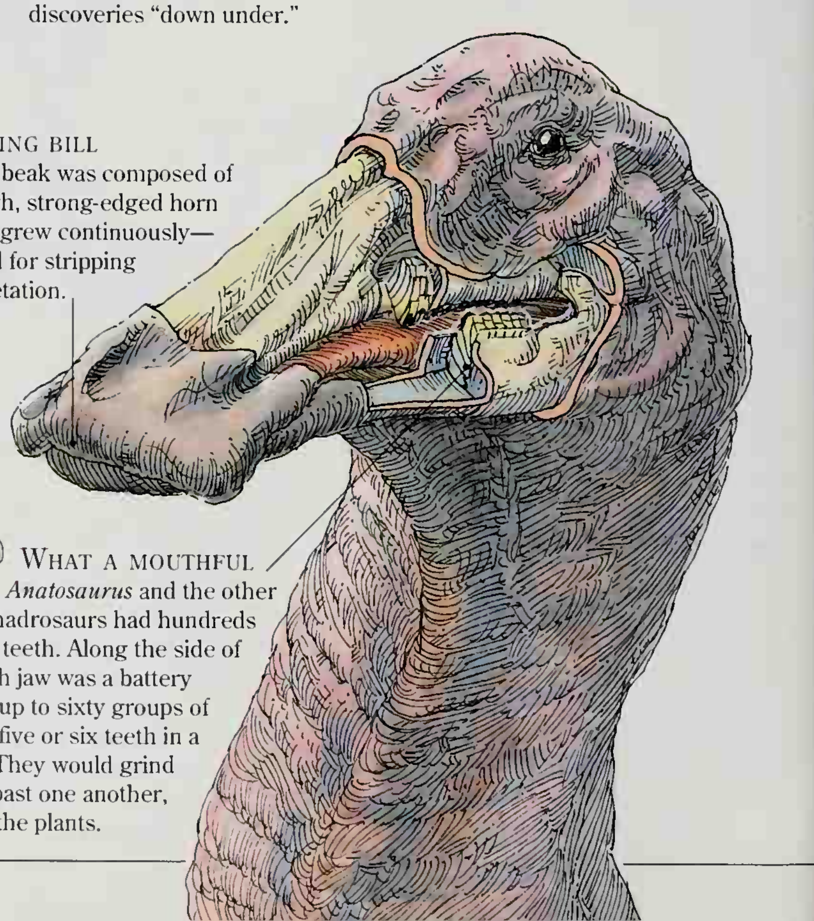
RAKING IT IN
Rows of small, slim, blunt teeth with gaps between them were ideal for raking leaves and buds from trees and for pulling fruits and seeds from plants.

DOWN UNDER
Rhoetosaurus was a medium-size herbivore whose remains were found near Brisbane, Australia, in 1924. It lived during the Jurassic period, around 150 to 200 million years ago. The fossils were one of the first major dinosaur discoveries "down under."

BATTERY-TOOTHED DUCKBILL
Anatosaurus was a 39.4-foot (12-meter)-long hadrosaur or "duck-billed" dinosaur. Behind its long, horn-covered beak were rows of strong cheek teeth, able to grind hard twigs and pine cones to a mulch.



TEAMS OF TEETH
New batches of hadrosaur teeth grew continuously, from the outside of the upper jaw and the inside of the lower jaw. The plates of enamel wore more slowly than the rest of the tooth, giving a ridged surface for up-and-down chewing motions.

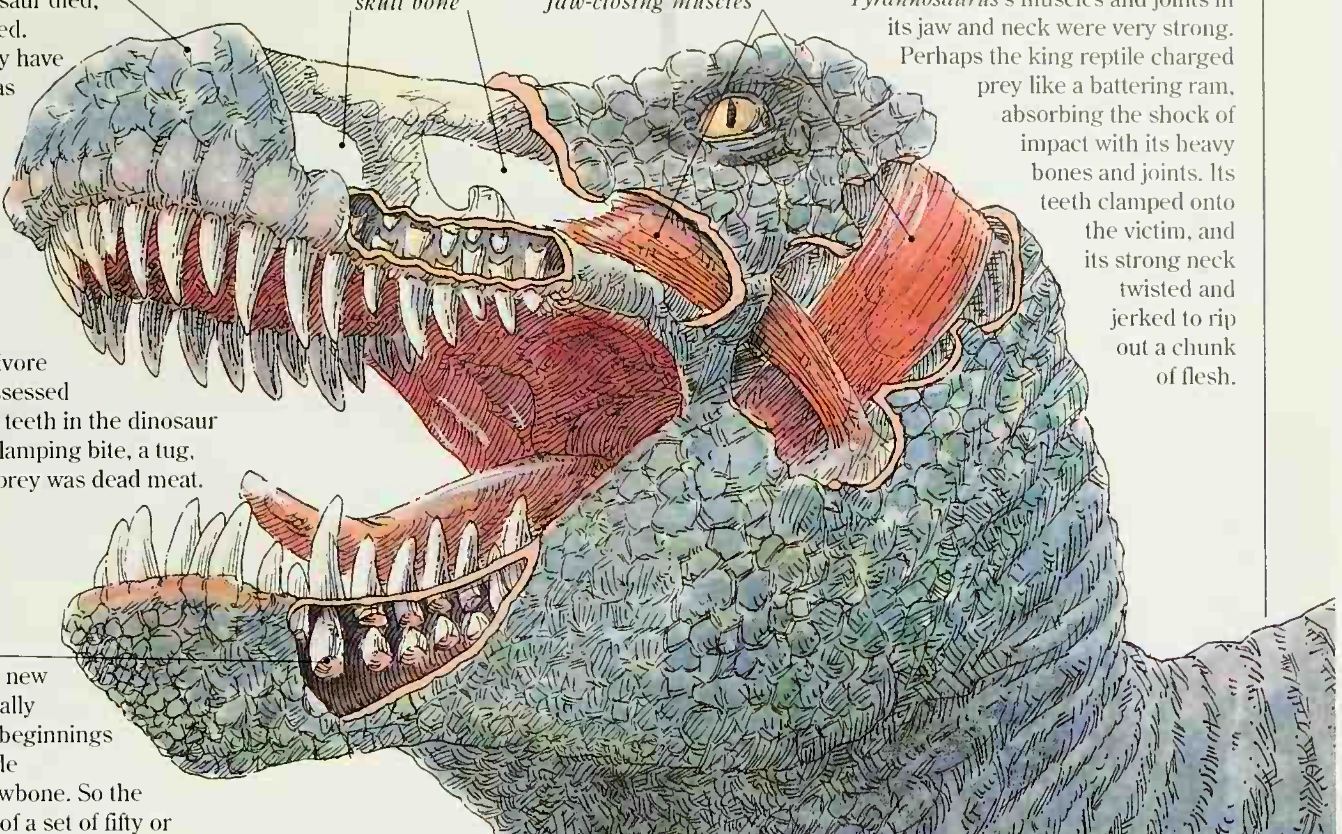


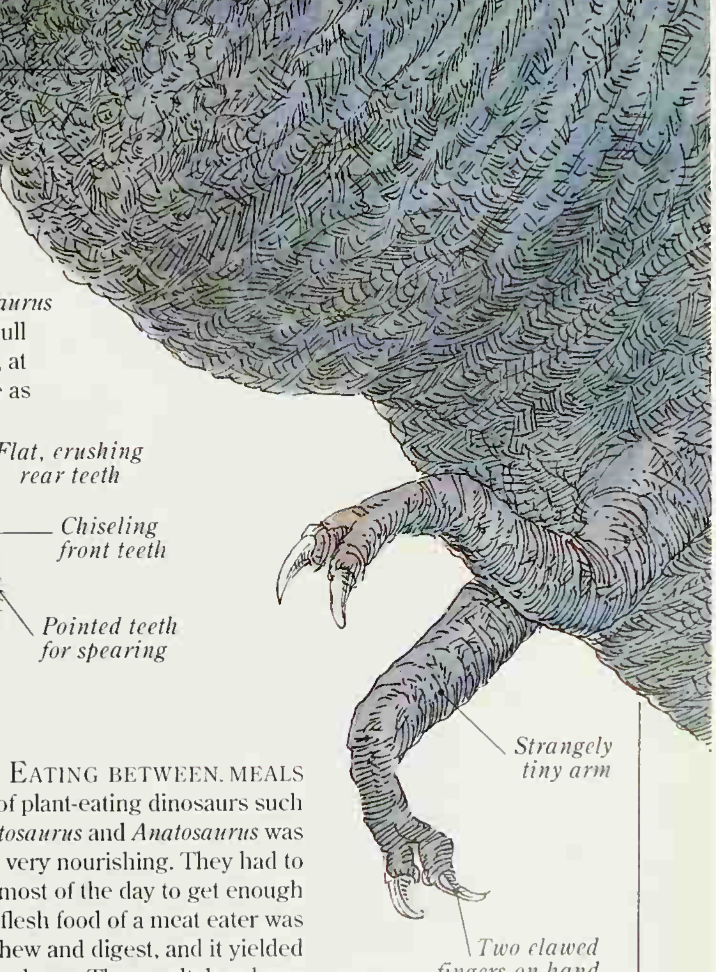
BITING BILL
The beak was composed of tough, strong-edged horn that grew continuously—ideal for stripping vegetation.

WHAT A MOUTHFUL
Anatosaurus and the other hadrosaurs had hundreds of teeth. Along the side of each jaw was a battery with up to sixty groups of teeth, five or six teeth in a group. They would grind and rub past one another, crushing the plants.

SCAVENGING BY SMELL?
When a large dinosaur died, it rotted and smelled. *Tyrannosaurus* may have been a scavenger as well as a hunter. It probably followed the scent of rotting meat to its next meal.

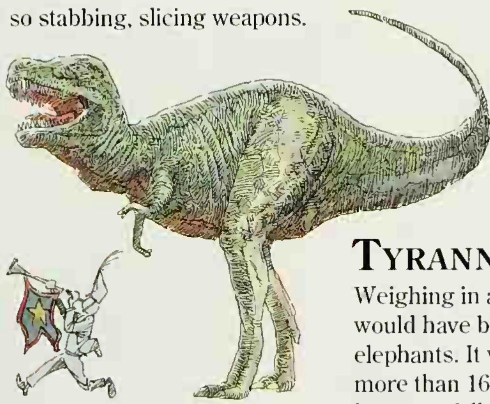
DINOSAUR SUPERSTRENGTH
Tyrannosaurus's muscles and joints in its jaw and neck were very strong. Perhaps the king reptile charged prey like a battering ram, absorbing the shock of impact with its heavy bones and joints. Its teeth clamped onto the victim, and its strong neck twisted and jerked to rip out a chunk of flesh.





JAWS OF DEATH
The supreme carnivore *Tyrannosaurus* possessed the most fearsome teeth in the dinosaur world. A lunge, a clamping bite, a tug, and a tear, and its prey was dead meat.

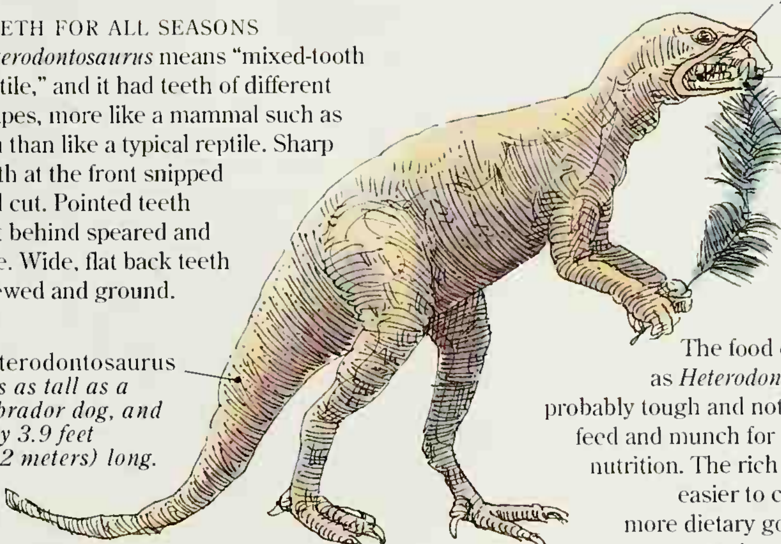
BABY TEETH
Throughout its life new teeth were continually growing from tiny beginnings in the sockets inside *Tyrannosaurus*'s jawbone. So the dinosaur was sure of a set of fifty or so stabbing, slicing weapons.



TYRANNOSAURUS

Weighing in at 7.08 tons (7 tonnes), *Tyrannosaurus* would have been heavier than two of today's bull elephants. It was also taller than most giraffes, at more than 16.4 feet (5 meters) high, and twice as long as a fully grown great white shark.

TEETH FOR ALL SEASONS
Heterodontosaurus means "mixed-tooth reptile," and it had teeth of different shapes, more like a mammal such as you than like a typical reptile. Sharp teeth at the front snipped and cut. Pointed teeth just behind speared and tore. Wide, flat back teeth chewed and ground.

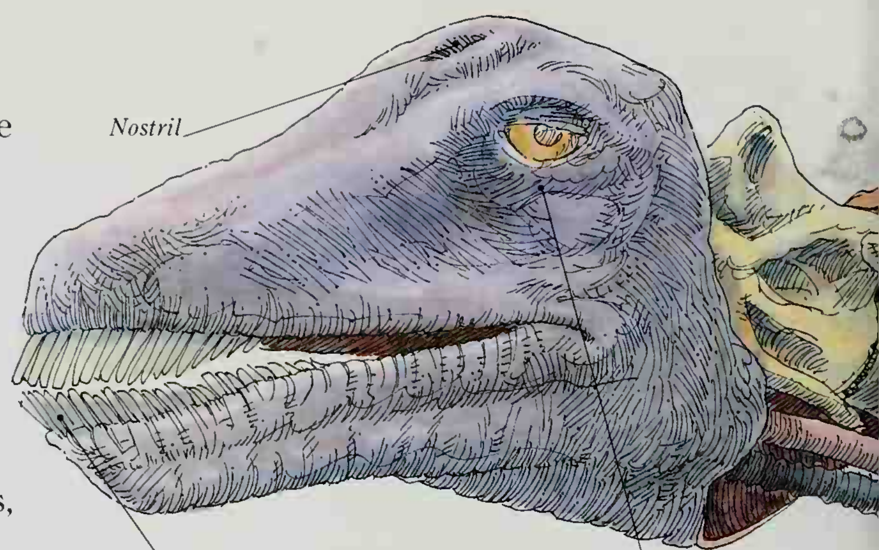


Heterodontosaurus *was as tall as a Labrador dog, and only 3.9 feet (1.2 meters) long.*

EATING BETWEEN MEALS
The food of plant-eating dinosaurs such as *Heterodontosaurus* and *Anatosaurus* was probably tough and not very nourishing. They had to feed and munch for most of the day to get enough nutrition. The rich flesh food of a meat eater was easier to chew and digest, and it yielded more dietary goodness. The result: lazy large carnivores and ever-eating herbivores.

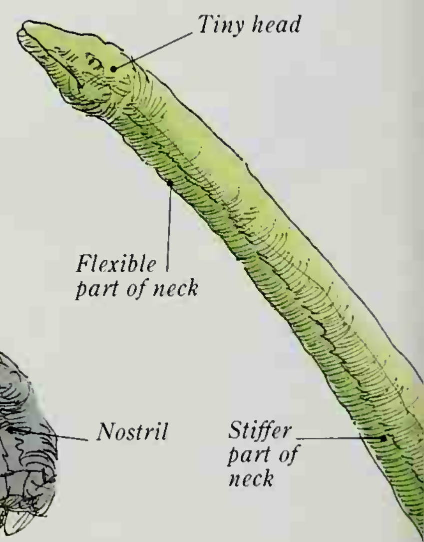
Neck and neck

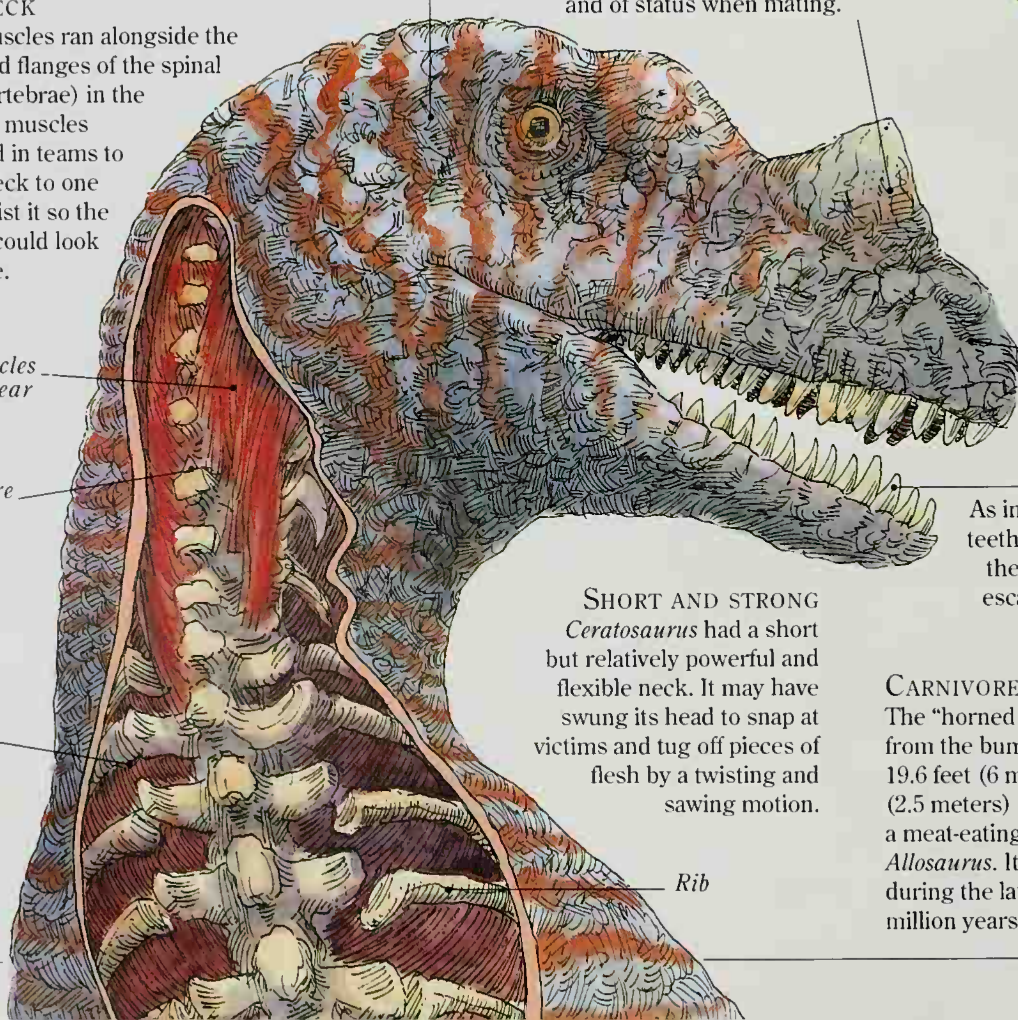
The famous swan's neck has nothing on the immensely long, snaking necks of some dinosaurs. Members of the sauropod group, such as *Diplodocus* and *Apatosaurus*, were the champion stretched necks. But why did the process of evolution come up with such a bizarre body plan? Standing in one spot, *Diplodocus* could sweep its head in an arc almost 65.6 feet (20 meters) across, saving energy while stripping the surrounding low vegetation of nourishment. That done, it could stretch up and reach plant food 16 to 19 feet (5 to 6 meters) above the ground, all without shifting its immense bulk. After craning its neck to look and sniff for predators and other dangers, the giant dinosaur would lumber on to the next vegetable patch.



A row of pencils
Diplodocus had two arcs of pencillike teeth at the front of its jaws, but its jaw muscles were weak. This dinosaur probably just raked off its leafy food and swallowed it straightaway.

Small head
The eyes and nostrils were set to the rear and top of *Diplodocus*'s tiny head. At one time, people believed that these types of dinosaurs lived in deep lakes and that the long neck was a snorkel or underwater breathing tube.





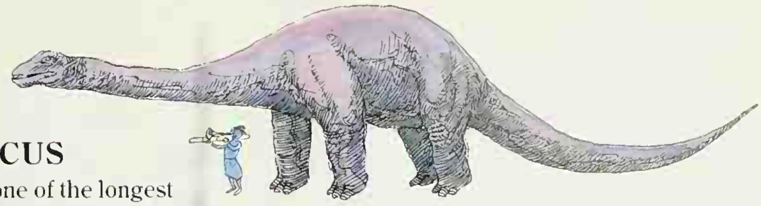
Bump on the head
The rhinolike nose lump had a core of bone. Its function is not clear. Possibly it was a sign of maturity and of status when mating.

Flexi-neck
Sets of muscles ran alongside the prongs and flanges of the spinal bones (vertebrae) in the neck. The muscles contracted in teams to pull the neck to one side or twist it so the dinosaur could look to the side.

No escape
As in other carnosaurs, the teeth curved backward into the mouth, to prevent the escape of struggling prey.

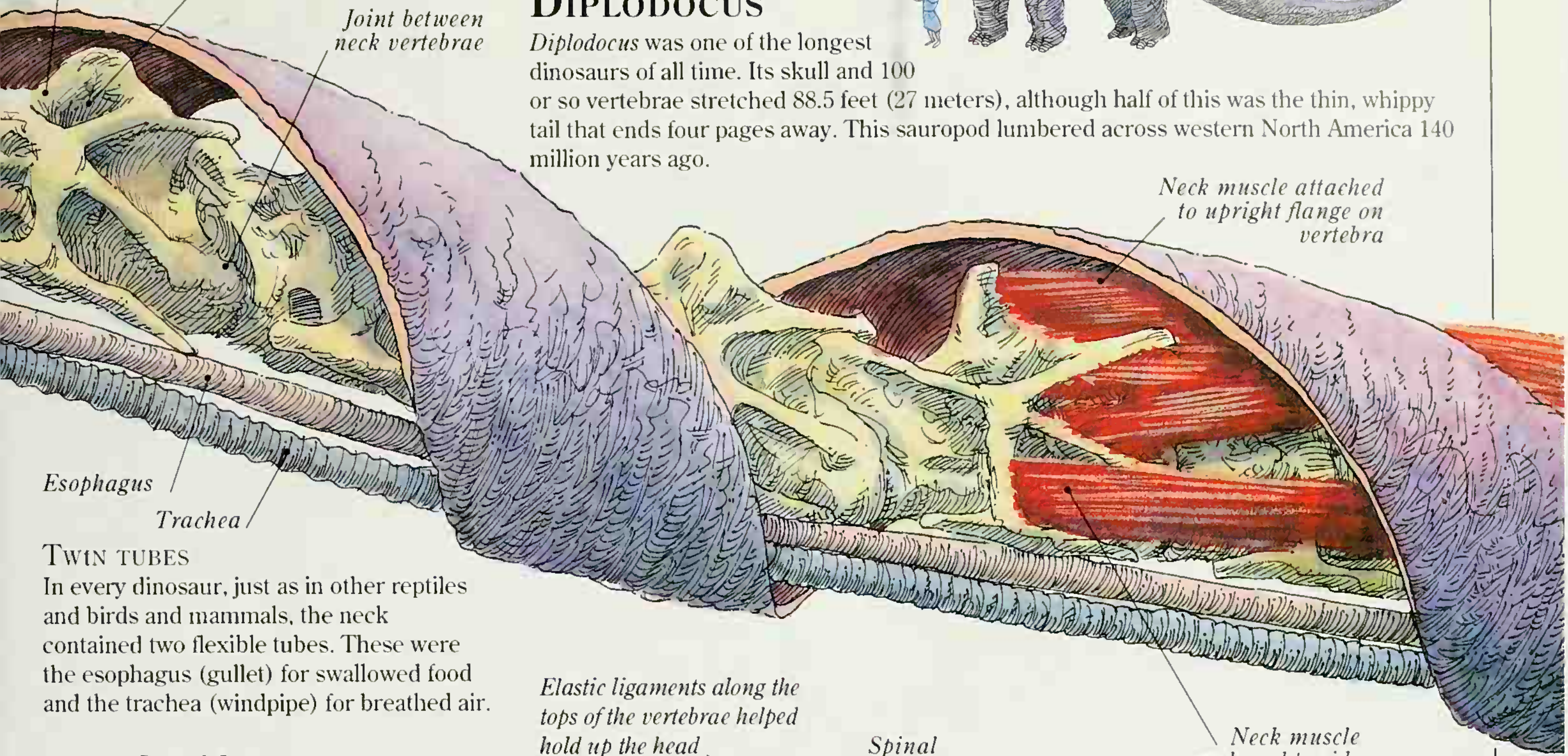
Short and strong
Ceratosaurus had a short but relatively powerful and flexible neck. It may have swung its head to snap at victims and tug off pieces of flesh by a twisting and sawing motion.

Carnivore cousins
The "horned reptile" *Ceratosaurus* is named from the bump on its nose. It was some 19.6 feet (6 meters) long and stood 8.2 feet (2.5 meters) high. Fossils indicate that it was a meat-eating relative of the better-known *Allosaurus*. It stalked western North America during the late Jurassic period, about 150 million years ago.



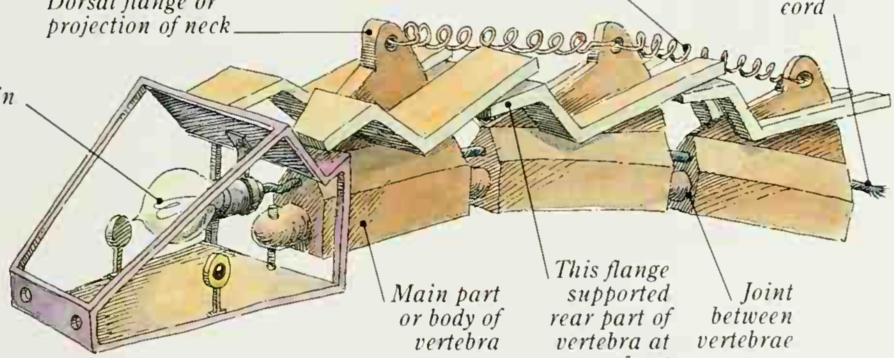
Diplodocus

Diplodocus was one of the longest dinosaurs of all time. Its skull and 100 or so vertebrae stretched 88.5 feet (27 meters), although half of this was the thin, whippy tail that ends four pages away. This sauropod lumbered across western North America 140 million years ago.



Twin tubes

In every dinosaur, just as in other reptiles and birds and mammals, the neck contained two flexible tubes. These were the esophagus (gullet) for swallowed food and the trachea (windpipe) for breathed air.

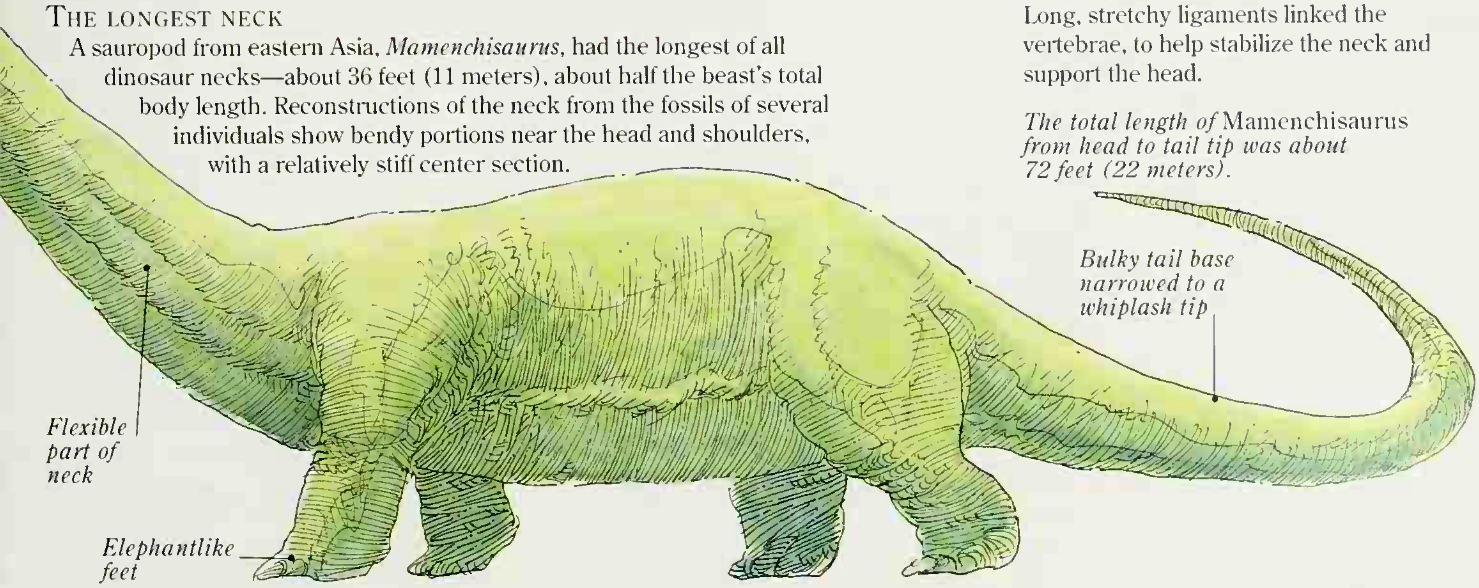


How the neck worked

This mechanical neck shows the main dinosaur features. Each vertebra of the spine had bony projections called processes or flanges on the top and sides, to which the muscles were attached. Between these and above the main part, or body, of each vertebra was a hole. The holes lined up and formed a tunnel that protected the spinal cord, the main bundle of nerves linking the brain to the body. Long, stretchy ligaments linked the vertebrae, to help stabilize the neck and support the head.

The longest neck

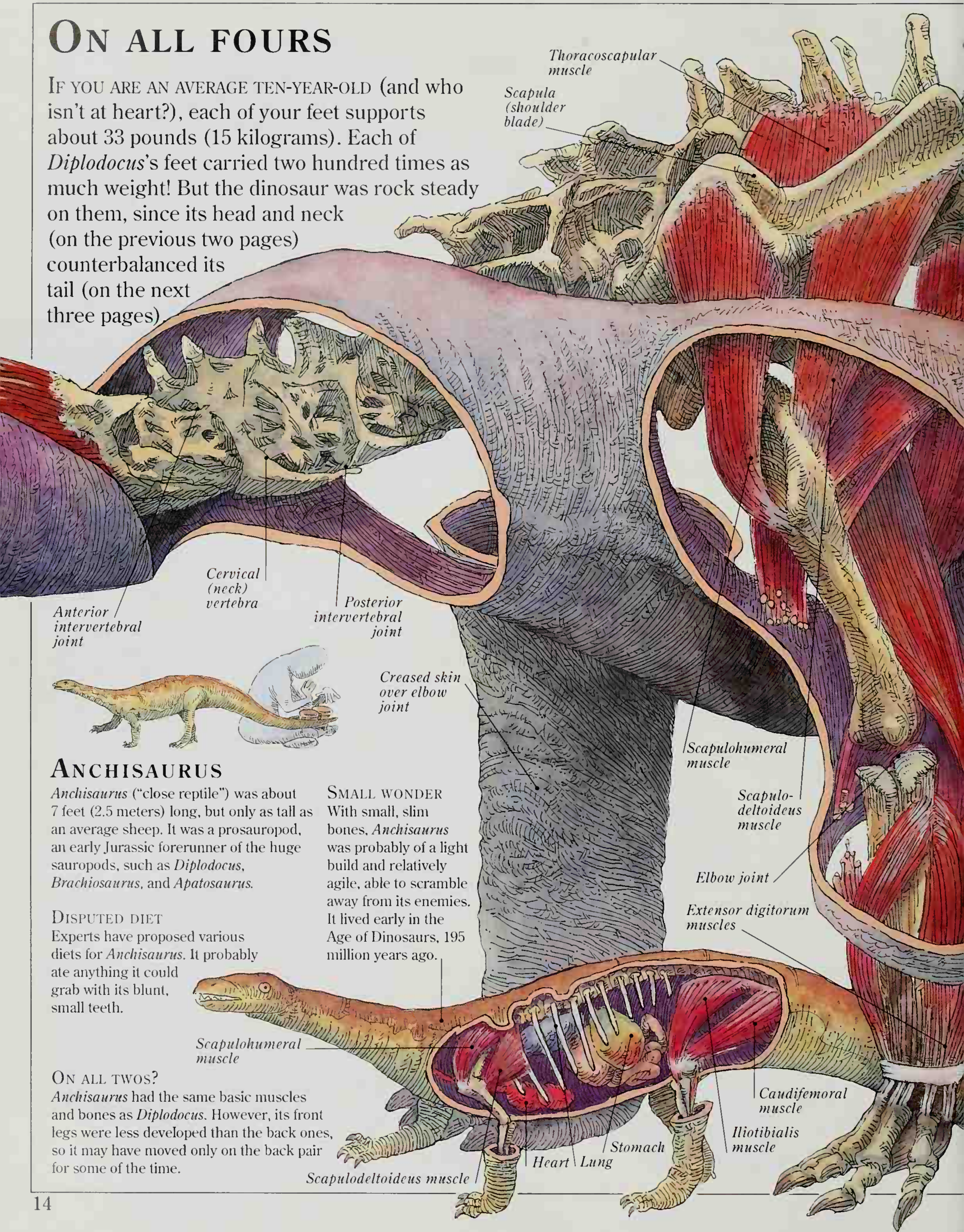
A sauropod from eastern Asia, *Mamenchisaurus*, had the longest of all dinosaur necks—about 36 feet (11 meters), about half the beast's total body length. Reconstructions of the neck from the fossils of several individuals show bendy portions near the head and shoulders, with a relatively stiff center section.



The total length of Mamenchisaurus *from head to tail tip was about 72 feet (22 meters).*

On all fours

If you are an average ten-year-old (and who isn't at heart?), each of your feet supports about 33 pounds (15 kilograms). Each of *Diplodocus*'s feet carried two hundred times as much weight! But the dinosaur was rock steady on them, since its head and neck (on the previous two pages) counterbalanced its tail (on the next three pages).



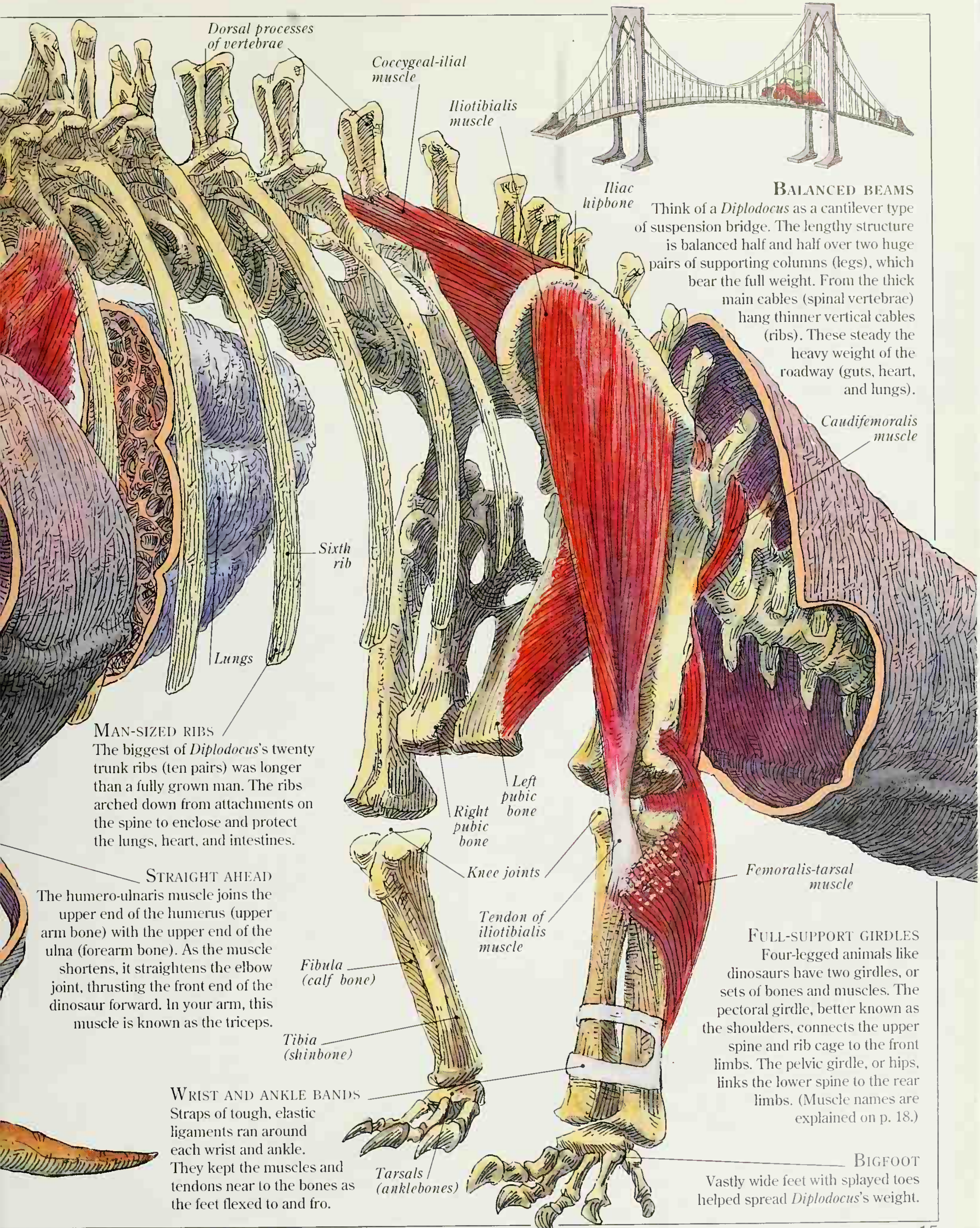
Anchisaurus

Anchisaurus ("close reptile") was about 7 feet (2.5 meters) long, but only as tall as an average sheep. It was a prosauropod, an early Jurassic forerunner of the huge sauropods, such as *Diplodocus*, *Brachiosaurus*, and *Apatosaurus*.

Disputed diet
Experts have proposed various diets for *Anchisaurus*. It probably ate anything it could grab with its blunt, small teeth.

Small wonder
With small, slim bones, *Anchisaurus* was probably of a light build and relatively agile, able to scramble away from its enemies. It lived early in the Age of Dinosaurs, 195 million years ago.

On all twos?
Anchisaurus had the same basic muscles and bones as *Diplodocus*. However, its front legs were less developed than the back ones, so it may have moved only on the back pair for some of the time.



Balanced beams

Think of a *Diplodocus* as a cantilever type of suspension bridge. The lengthy structure is balanced half and half over two huge pairs of supporting columns (legs), which bear the full weight. From the thick main cables (spinal vertebrae) hang thinner vertical cables (ribs). These steady the heavy weight of the roadway (guts, heart, and lungs).

Man-sized ribs

The biggest of *Diplodocus*'s twenty trunk ribs (ten pairs) was longer than a fully grown man. The ribs arched down from attachments on the spine to enclose and protect the lungs, heart, and intestines.

Straight ahead

The humero-ulnaris muscle joins the upper end of the humerus (upper arm bone) with the upper end of the ulna (forearm bone). As the muscle shortens, it straightens the elbow joint, thrusting the front end of the dinosaur forward. In your arm, this muscle is known as the triceps.

Wrist and ankle bands

Straps of tough, elastic ligaments ran around each wrist and ankle. They kept the muscles and tendons near to the bones as the feet flexed to and fro.

Full-support girdles

Four-legged animals like dinosaurs have two girdles, or sets of bones and muscles. The pectoral girdle, better known as the shoulders, connects the upper spine and rib cage to the front limbs. The pelvic girdle, or hips, links the lower spine to the rear limbs. (Muscle names are explained on p. 18.)

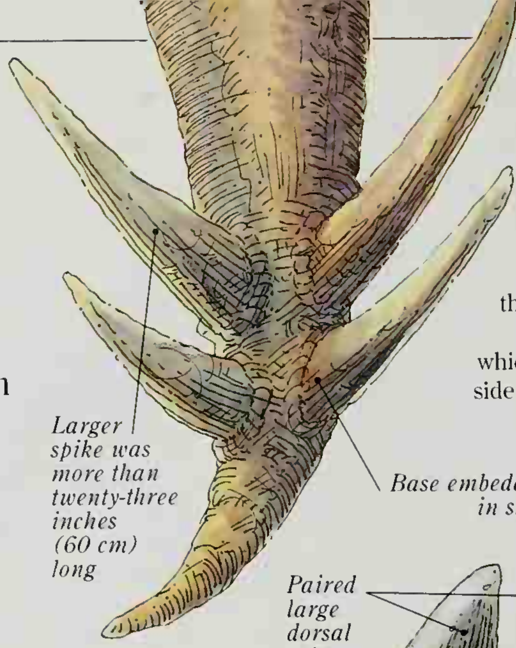
Bigfoot

Vastly wide feet with splayed toes helped spread *Diplodocus*'s weight.

Tail-enders

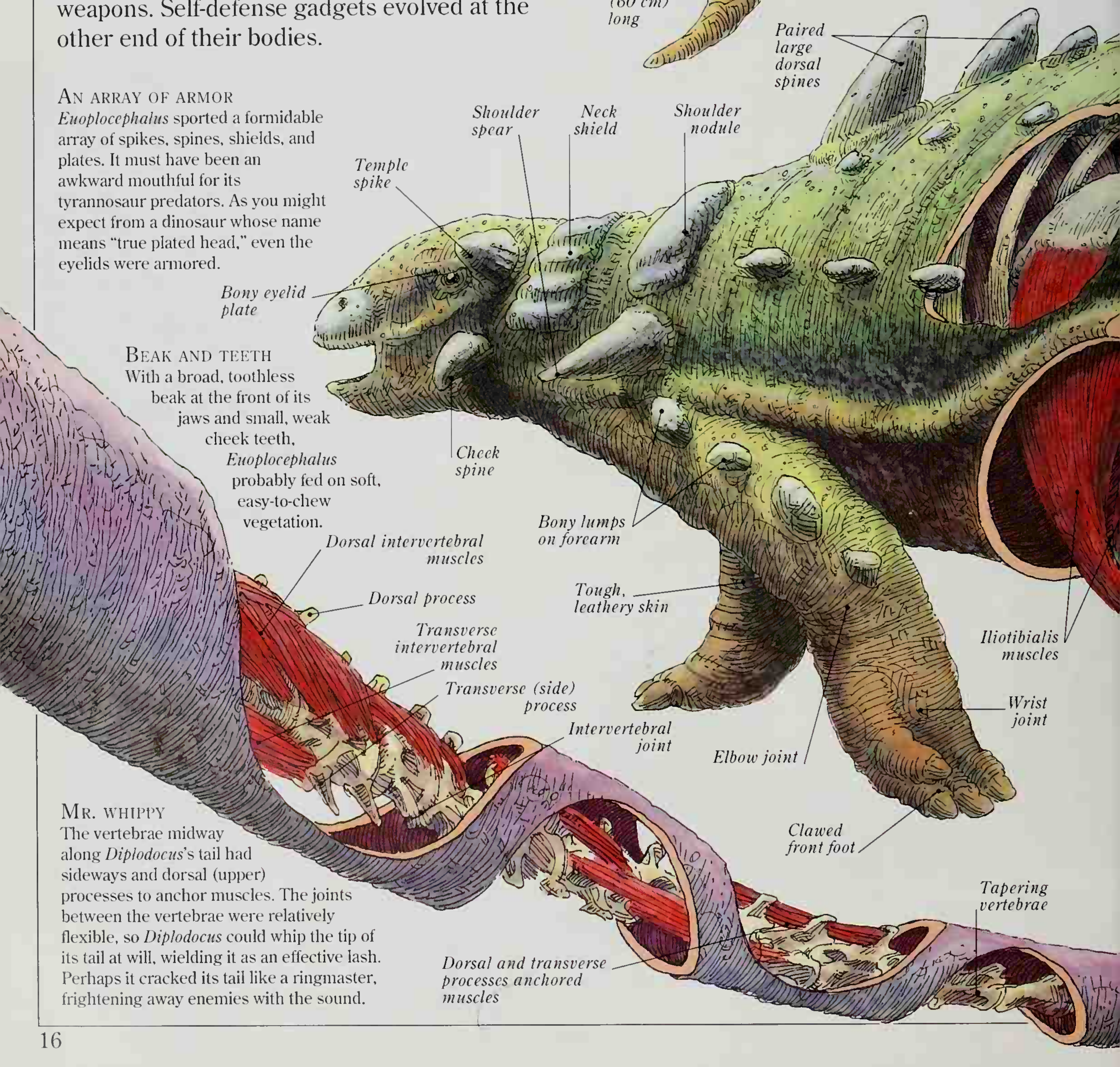
Dinosaur tails did more than just trail along behind their owners. They were long whips, spiky maces, muscle anchors, adjustable counterweights, steering rudders, or, in the case of *Euoplocephalus*, heavy clubs capable of delivering a knockout blow. The dinosaurs shown here were all plant eaters. They lacked the large, sharp teeth and claws of the carnivores, which doubled as both feeding utensils and defensive weapons. Self-defense gadgets evolved at the other end of their bodies.

Sharp, spiky rear spears
Stegosaurus (see p. 26) had two pointy pairs of bone-cored tail spikes. Together, they formed a fierce, macelike weapon, which was swung from side to side to puncture a predator.



An array of armor
Euoplocephalus sported a formidable array of spikes, spines, shields, and plates. It must have been an awkward mouthful for its tyrannosaur predators. As you might expect from a dinosaur whose name means "true plated head," even the eyelids were armored.

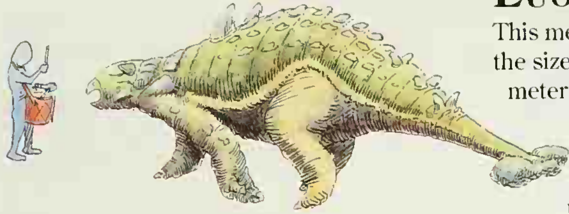
Beak and teeth
With a broad, toothless beak at the front of its jaws and small, weak cheek teeth, *Euoplocephalus* probably fed on soft, easy-to-chew vegetation.



Mr. whippy
The vertebrae midway along *Diplodocus*'s tail had sideways and dorsal (upper) processes to anchor muscles. The joints between the vertebrae were relatively flexible, so *Diplodocus* could whip the tip of its tail at will, wielding it as an effective lash. Perhaps it cracked its tail like a ringmaster, frightening away enemies with the sound.

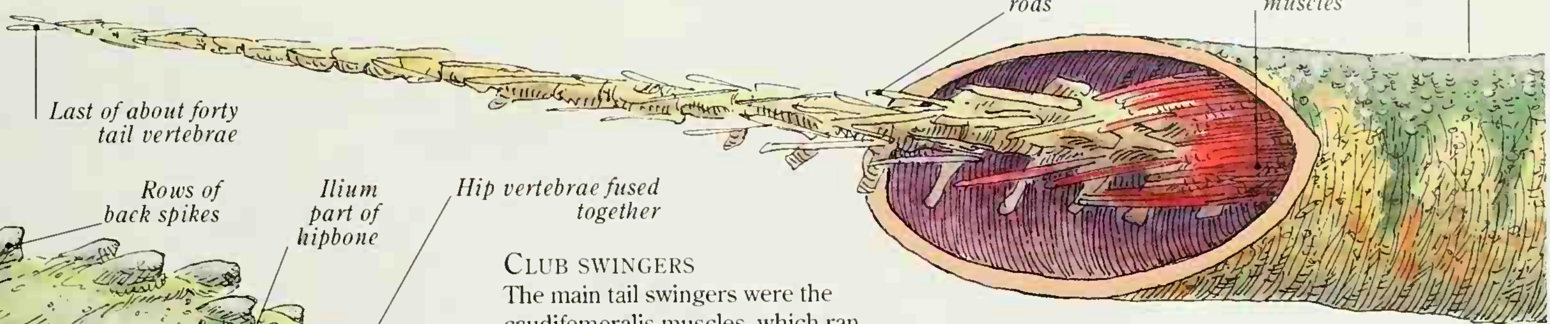
Euoplocephalus

This medium-size ankylosaur was about the size of a school minibus: 19.6 feet (6 meters) long, just taller than an adult, and 2.4 tons (2 tonnes) in weight. As dinosaurs go, it is fairly well known, from eighty-million-year-old fossils unearthed in Alberta, Canada.



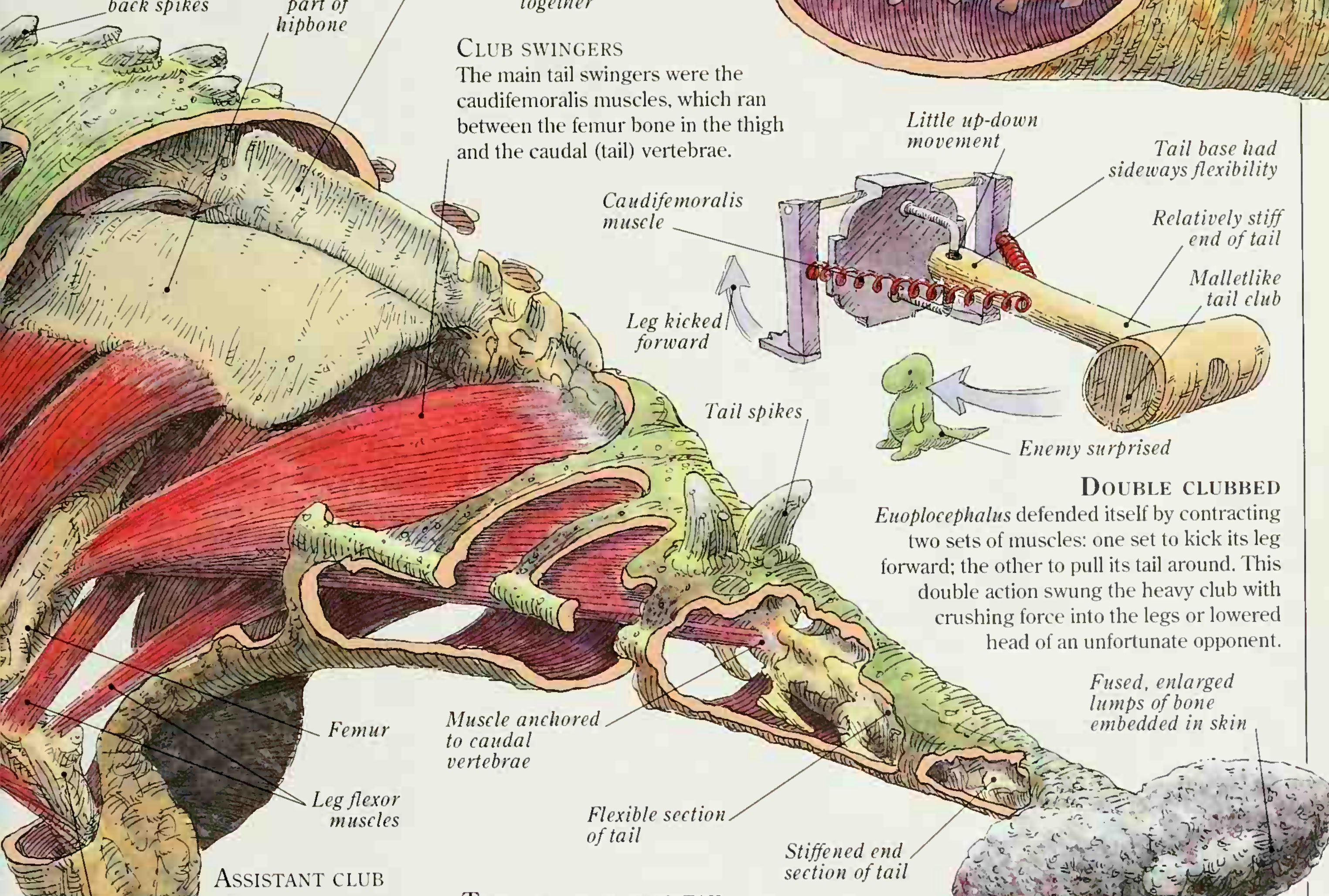
Tailing off the page

Below is *Pachycephalosaurus*'s shortish, stiffish tail. The rest of this two-legged "head butter" has charged over to the next page. The dinosaur used its tail chiefly as a counterbalance as it sprinted along with its body held horizontal.



Club swingers

The main tail swingers were the caudifemoralis muscles, which ran between the femur bone in the thigh and the caudal (tail) vertebrae.



Double clubbed

Euoplocephalus defended itself by contracting two sets of muscles: one set to kick its leg forward; the other to pull its tail around. This double action swung the heavy club with crushing force into the legs or lowered head of an unfortunate opponent.

Twin lumps

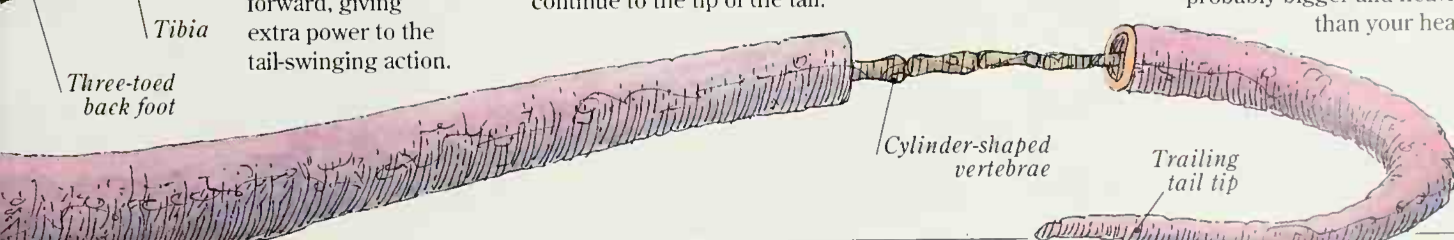
Each of the two bony lumps making up the tail club was probably bigger and heavier than your head.

Assistant club swingers

The iliotibialis muscles connecting the hip to the shin jerked the leg forward, giving extra power to the tail-swinging action.

The end of a long tail

Several pages and some seventy vertebral tailbones later, we bid good-bye to *Diplodocus*'s slim, tapering tail. The muscle flanges and side processes are gone. Small, rodlike vertebrae continue to the tip of the tail.

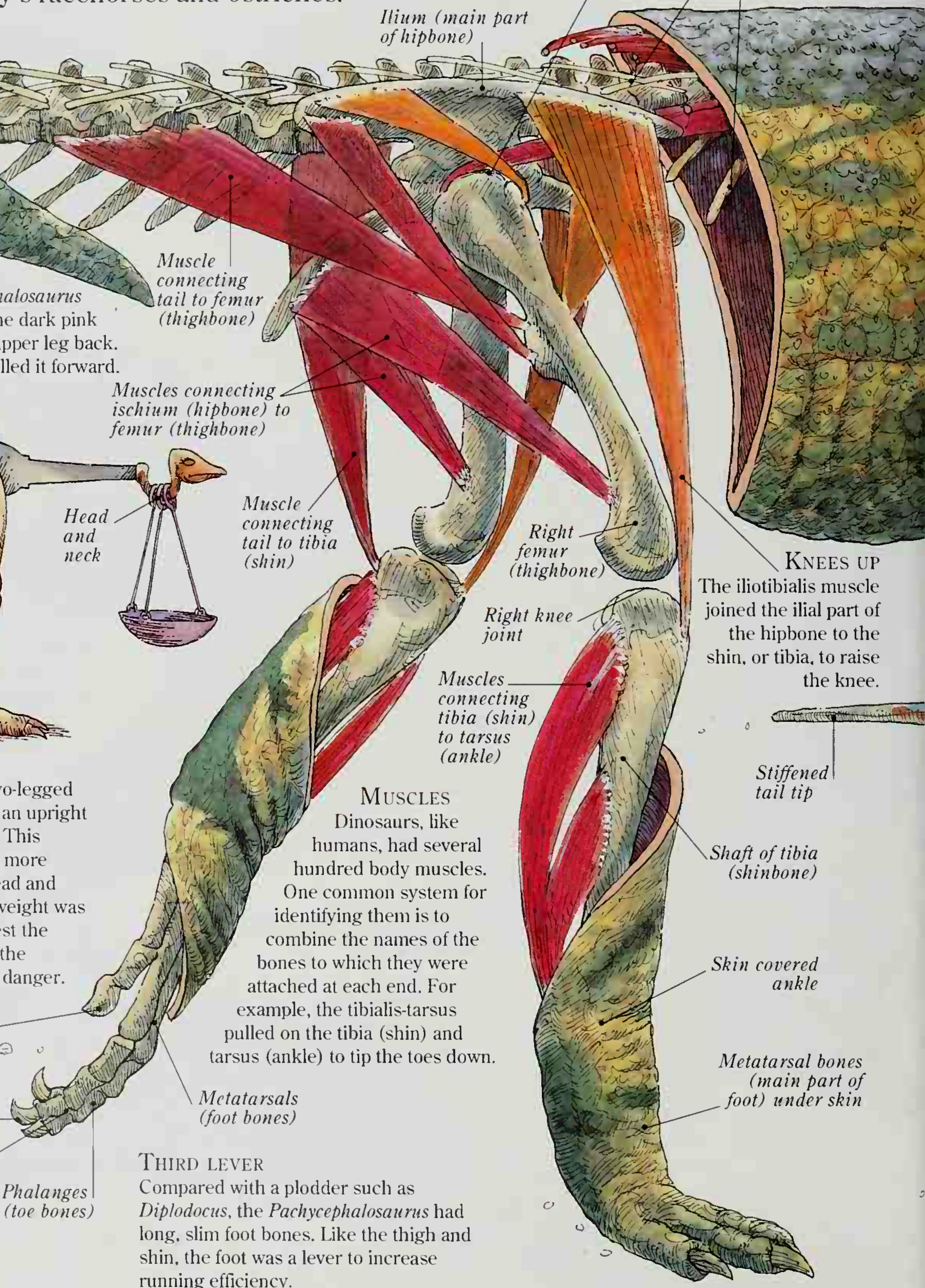


Up and running

Head down, neck straight out in front, tail stiff behind, body well balanced over muscular back legs, *Pachycephalosaurus* prepares to charge at a rival in the mating game. Many two-legged dinosaurs were slim and long-limbed, a sure sign of speed all those millions of years ago, just as it is in today's racehorses and ostriches.

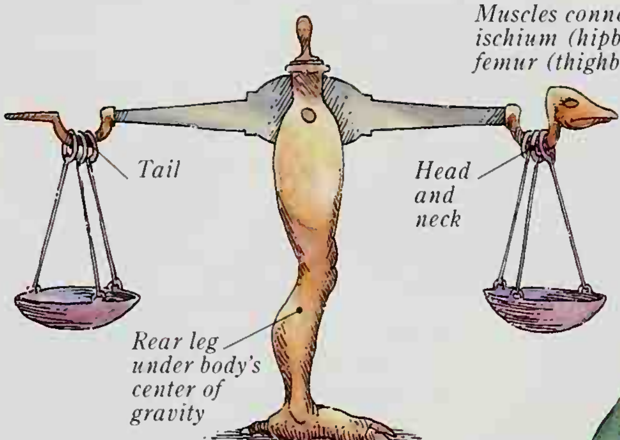
Rod-rigid

Small bony rods linked the vertebrae of the backbone and helped stiffen it in the back and hip area.



In the pink

The hip muscles of *Pachycephalosaurus* are color-coded for clarity. The dark pink ones (extensors) pulled the upper leg back. The orange ones (flexors) pulled it forward.



Knees up

The iliotibialis muscle joined the ilial part of the hipbone to the shin, or tibia, to raise the knee.

Balancing the body

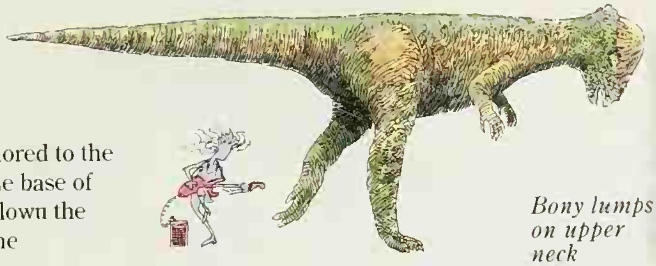
Some older reconstructions of two-legged dinosaurs show them running in an upright position, chest and neck vertical. This would have been very tiring. It is more likely that the dinosaur tipped head and neck forward so that the body's weight was centered over the rear legs. At rest the body would tilt more upright, so the dinosaur could scan and sniff for danger.

Muscles

Dinosaurs, like humans, had several hundred body muscles. One common system for identifying them is to combine the names of the bones to which they were attached at each end. For example, the tibialis-tarsus pulled on the tibia (shin) and tarsus (ankle) to tip the toes down.

Third lever

Compared with a plodder such as *Diplodocus*, the *Pachycephalosaurus* had long, slim foot bones. Like the thigh and shin, the foot was a lever to increase running efficiency.

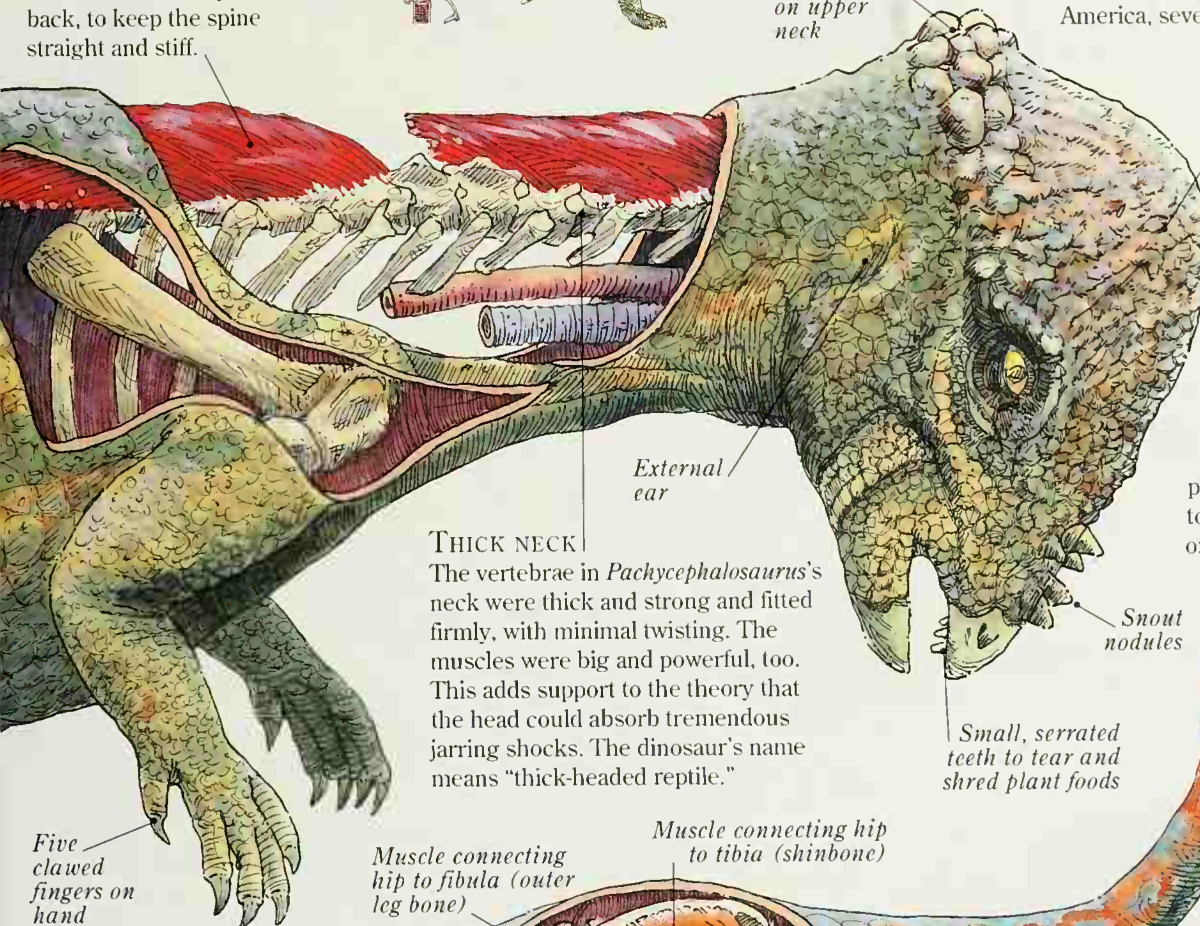


Pachycephalosaurus

Pachycephalosaurus was the largest of a dinosaur group memorably called the bone heads or head butters. It was more than 24.2 feet (8 meters) long and 16.4 feet (5 meters) standing upright, and its remains are scarce and fragmentary. It roamed what is now western North America, seventy million years ago.

Stiff-backed

Strips of muscle anchored to the vertebrae ran from the base of the neck all the way down the back, to keep the spine straight and stiff.

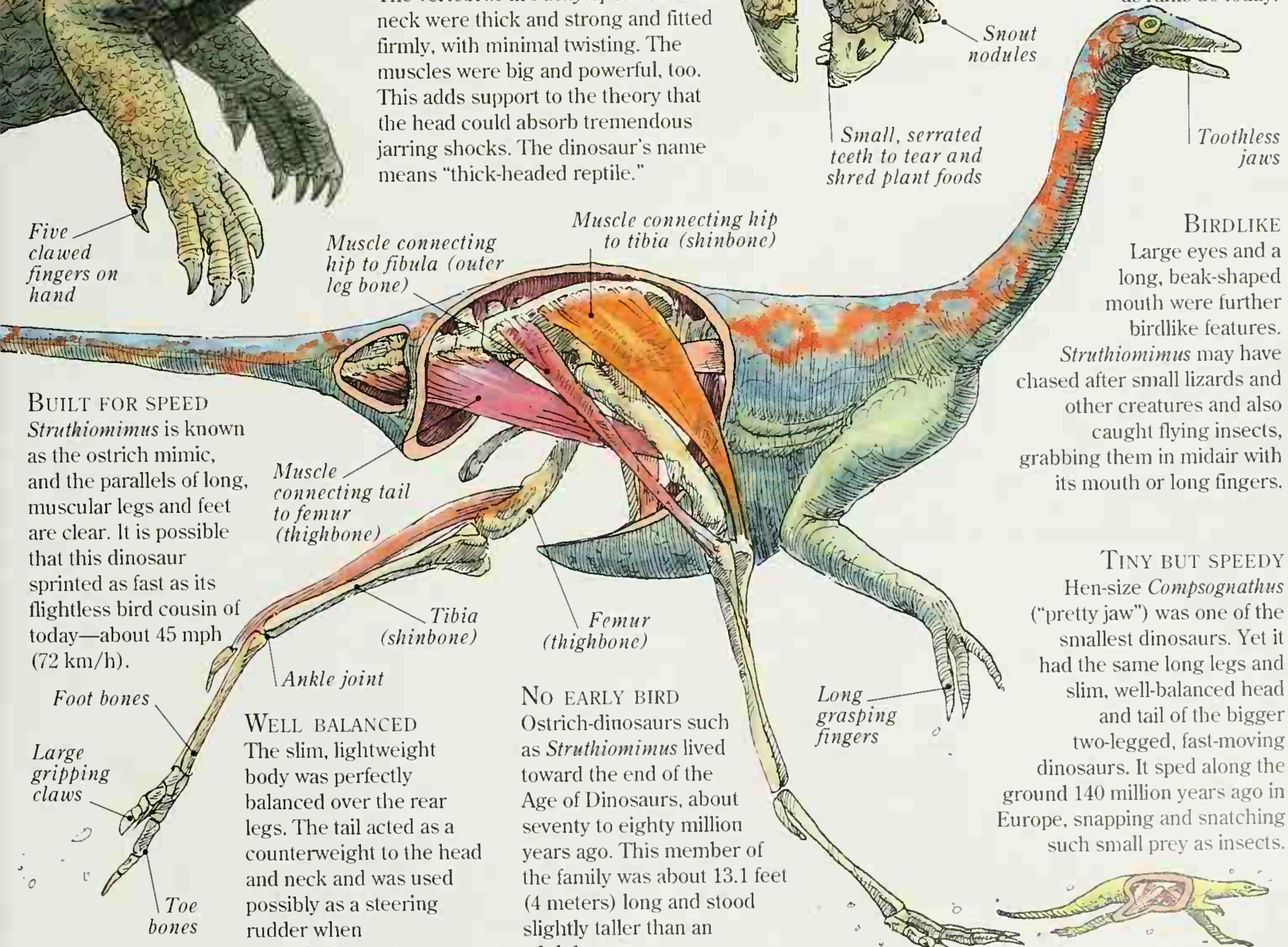


The bone dome

Pachycephalosaurus's head was topped by a massive "crash helmet" of bone, perhaps used as a form of defense. These dinosaurs may have charged at enemies or perhaps butted each other to take charge of the herd, or a female at mating time, as rams do today.

Thick neck

The vertebrae in *Pachycephalosaurus*'s neck were thick and strong and fitted firmly, with minimal twisting. The muscles were big and powerful, too. This adds support to the theory that the head could absorb tremendous jarring shocks. The dinosaur's name means "thick-headed reptile."



Birdlike

Large eyes and a long, beak-shaped mouth were further birdlike features. *Struthiomimus* may have chased after small lizards and other creatures and also caught flying insects, grabbing them in midair with its mouth or long fingers.

Built for speed

Struthiomimus is known as the ostrich mimic, and the parallels of long, muscular legs and feet are clear. It is possible that this dinosaur sprinted as fast as its flightless bird cousin of today—about 45 mph (72 km/h).

Well balanced

The slim, lightweight body was perfectly balanced over the rear legs. The tail acted as a counterweight to the head and neck and was used possibly as a steering rudder when *Struthiomimus* ran.

No early bird

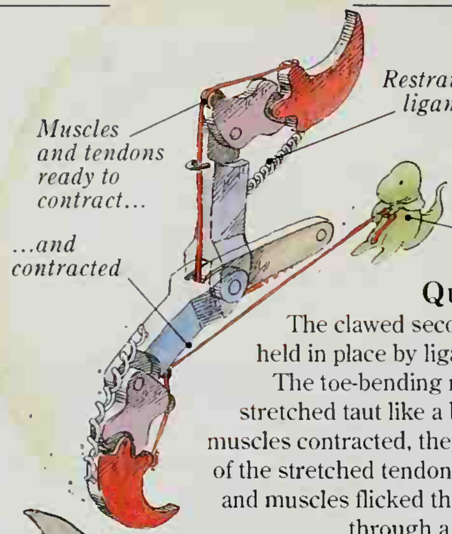
Ostrich-dinosaurs such as *Struthiomimus* lived toward the end of the Age of Dinosaurs, about seventy to eighty million years ago. This member of the family was about 13.1 feet (4 meters) long and stood slightly taller than an adult human.

Tiny but speedy

Hen-size *Compsognathus* ("pretty jaw") was one of the smallest dinosaurs. Yet it had the same long legs and slim, well-balanced head and tail of the bigger two-legged, fast-moving dinosaurs. It sped along the ground 140 million years ago in Europe, snapping and snatching such small prey as insects.

Slash and gnash

Some dinosaurs lived by feeding on others; it was a dinosaur-eat-dinosaur world. Clues in its fossilized remains tell you if a dinosaur was a hunter or the hunted. Sharp teeth and pointy claws denote both the hunting weapons and the defensive tools of the predator. A fine dinosaur example was the pack-hunting, human-size "terrible claw" *Deinonychus*. Its sharp, daggerlike claw on each foot could slash, maim, and dismember a victim with one deadly swipe.

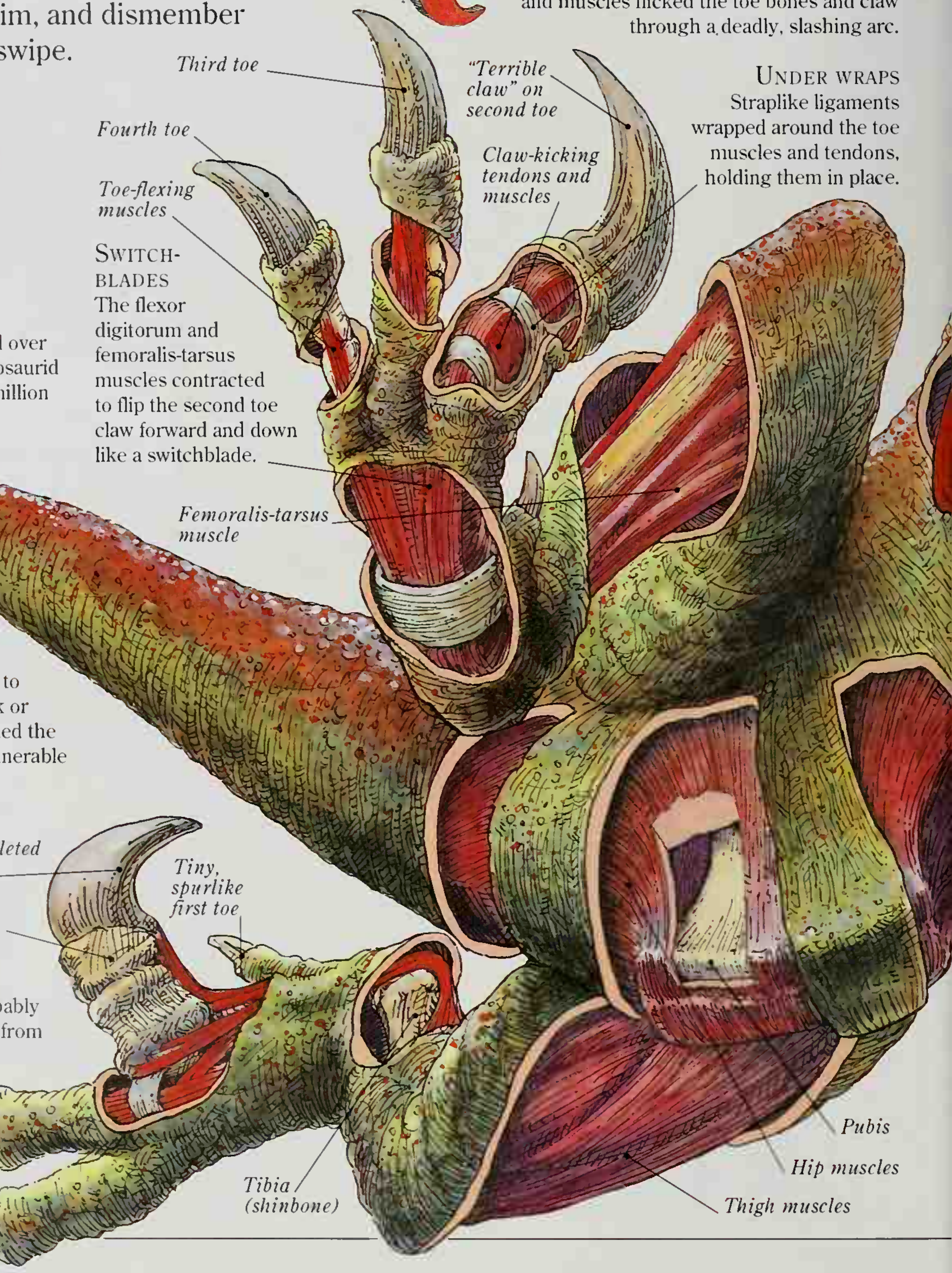


Quick flick claw

The clawed second toe was normally held in place by ligaments and muscles. The toe-bending muscles and tendons stretched taut like a bowstring. When the muscles contracted, they released the power of the stretched tendons. Together, tendons and muscles flicked the toe bones and claw through a deadly, slashing arc.

Deinonychus

Less than 6.6 feet (2 meters) tall, and over 9.8 feet (3 meters) long, the dromaeosaurid *Deinonychus* lived about a hundred million years ago in western North America.



Under wraps

Straplike ligaments wrapped around the toe muscles and tendons, holding them in place.

Switch-blades

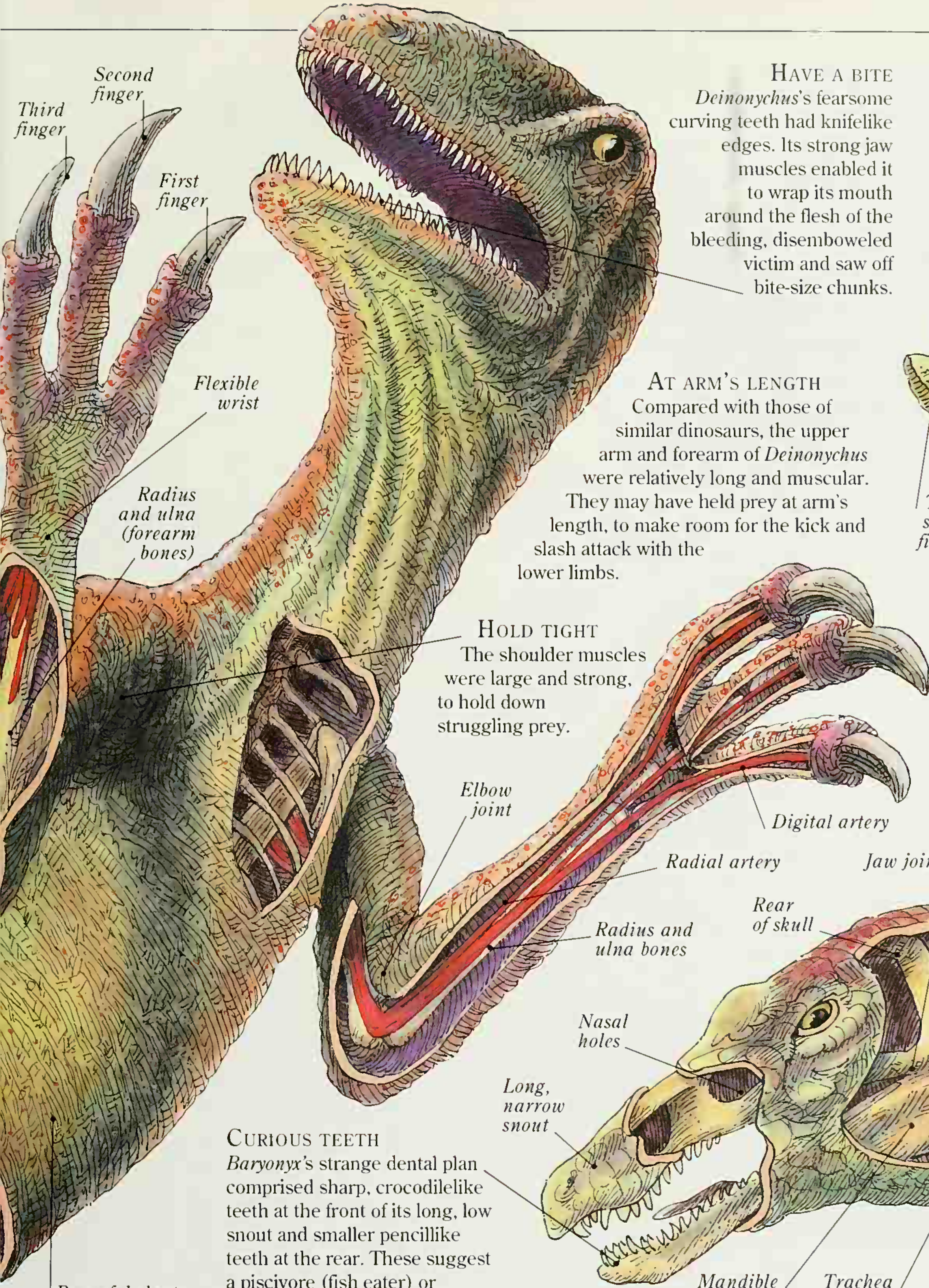
The flexor digitorum and femoralis-tarsus muscles contracted to flip the second toe claw forward and down like a switchblade.

Wolf of the dinosaur age?

Several skeletons of *Deinonychus* were found together, indicating that these dinosaurs may have hunted in packs to tackle larger prey, as wolves hunt elk or reindeer today. Some bit and scratched the victim, while others slashed at its vulnerable belly and disemboweled it with their terrible claws.

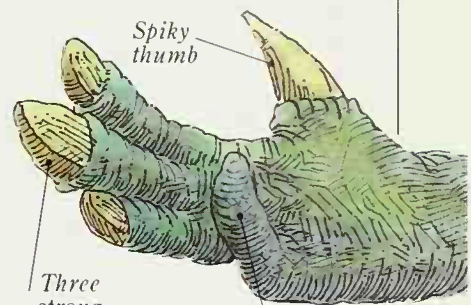
Toe holdup

As *Deinonychus* moved along, it probably held the huge-clawed second toe up from the ground, to keep it razor sharp and poised for action. The third and fourth toes were large and strong, well suited for walking and running.



HAVE A BITE
Deinonychus's fearsome curving teeth had knifelike edges. Its strong jaw muscles enabled it to wrap its mouth around the flesh of the bleeding, disemboweled victim and saw off bite-size chunks.

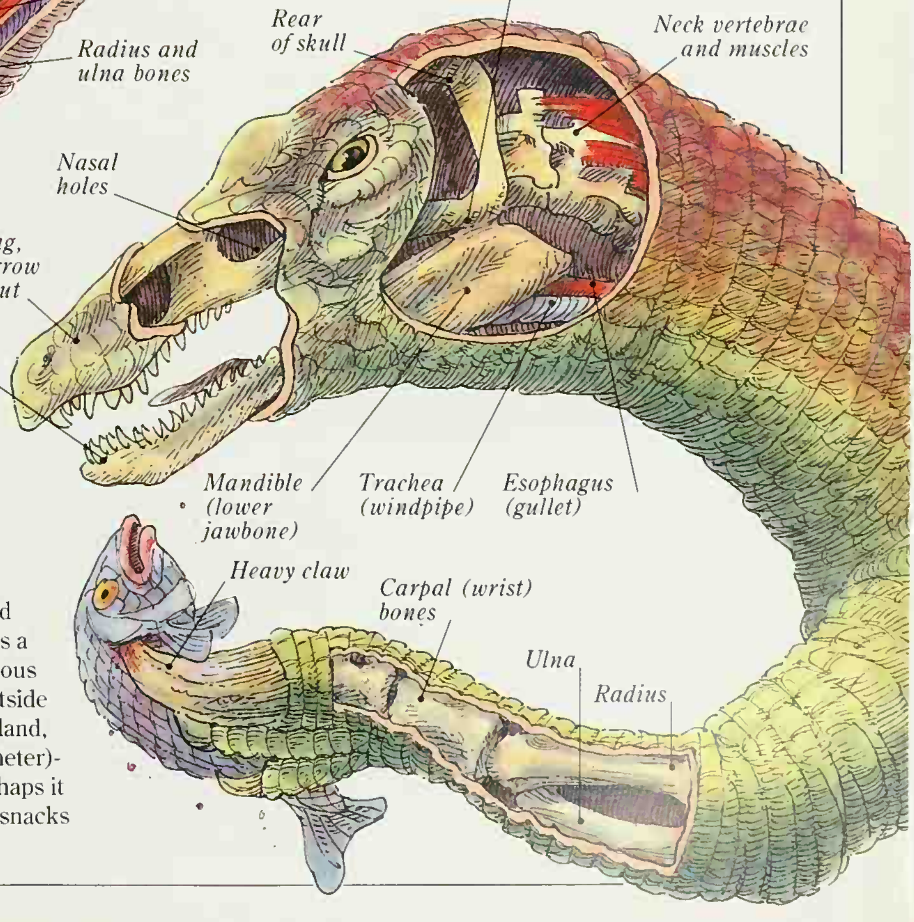
THUMBS UP
The herbivore *Iguanodon* (p. 8) had a peculiar spiky claw on its thumb. This may have been a jabber-stabber defense weapon. The three main hooflike fingers were strong, for four-legged walking.



AT ARM'S LENGTH
Compared with those of similar dinosaurs, the upper arm and forearm of *Deinonychus* were relatively long and muscular. They may have held prey at arm's length, to make room for the kick and slash attack with the lower limbs.

HOLD TIGHT
The shoulder muscles were large and strong, to hold down struggling prey.

GRAPPLING HOOKS
Three sharp, talonlike claws tipped *Deinonychus*'s fingers. Roughened patches on the arm and finger bones suggest powerful musculature. Perhaps this hunter jabbed its finger claws into a potential meal, like grappling hooks.

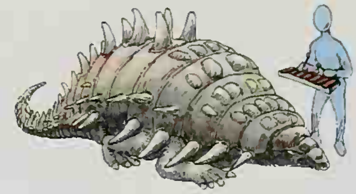


CURIOUS TEETH
Baryonyx's strange dental plan comprised sharp, crocodilelike teeth at the front of its long, low snout and smaller pencillike teeth at the rear. These suggest a piscivore (fish eater) or perhaps the probing snout of a scavenger.

GONE FISHIN'
Although "heavy claw" *Baryonyx* may have fished England's rivers about 120 million years ago, it is a relatively recent dinosaur discovery. The enormous claw, 12.1 inches (31 centimeters) around its outside edge, was unearthed in a clay pit in Surrey, England, in 1983. The reconstruction of this 26.2-feet (8-meter)-long theropod shows this claw on the hand. Perhaps it was a fishing hook or a gaff to jerk shiny-scaled snacks from the shallows.

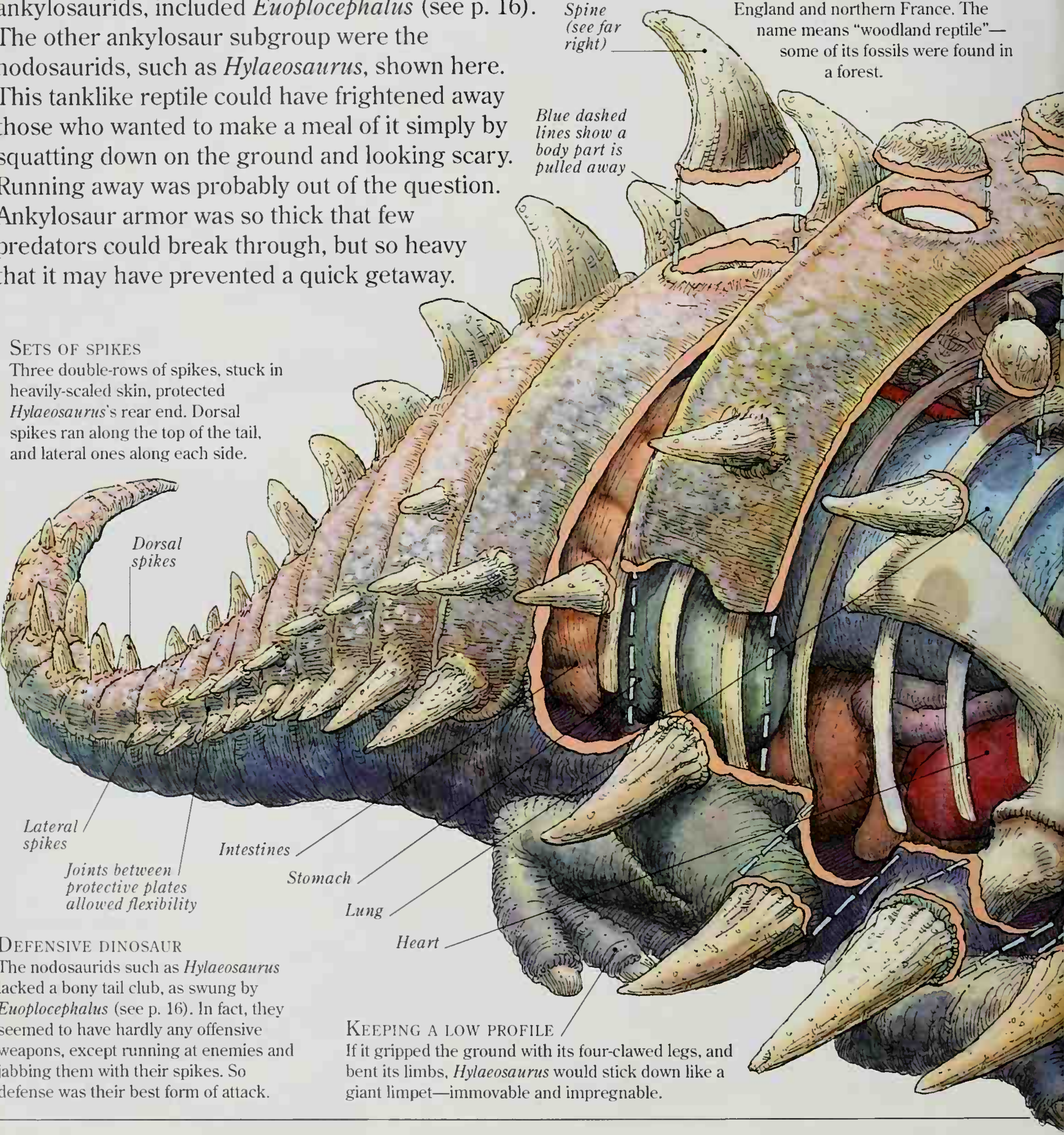
ARMORED AND DANGEROUS

MEDIEVAL KNIGHTS IN ARMOR were mere amateurs compared to the ankylosaurs, the “fused reptile” dinosaurs. The name refers to the way horny scales and plates of bone evolved and joined together to protect almost every part of their anatomy, except the ever-vulnerable belly. One subgroup, the ankylosaurids, included *Euoplocephalus* (see p. 16). The other ankylosaur subgroup were the nodosaurids, such as *Hylaeosaurus*, shown here. This tanklike reptile could have frightened away those who wanted to make a meal of it simply by squatting down on the ground and looking scary. Running away was probably out of the question. Ankylosaur armor was so thick that few predators could break through, but so heavy that it may have prevented a quick getaway.



HYLAEOSAURUS

Thirteen feet (4 meters) long, and twenty times the weight of a human, this squat beast was one of the original *Dinosauria* named by Richard Owen in 1841. It lived 130 million years ago in southern England and northern France. The name means “woodland reptile”—some of its fossils were found in a forest.



SETS OF SPIKES

Three double-rows of spikes, stuck in heavily-scaled skin, protected *Hylaeosaurus*'s rear end. Dorsal spikes ran along the top of the tail, and lateral ones along each side.

DEFENSIVE DINOSAUR

The nodosaurids such as *Hylaeosaurus* lacked a bony tail club, as swung by *Euoplocephalus* (see p. 16). In fact, they seemed to have hardly any offensive weapons, except running at enemies and jabbing them with their spikes. So defense was their best form of attack.

KEEPING A LOW PROFILE

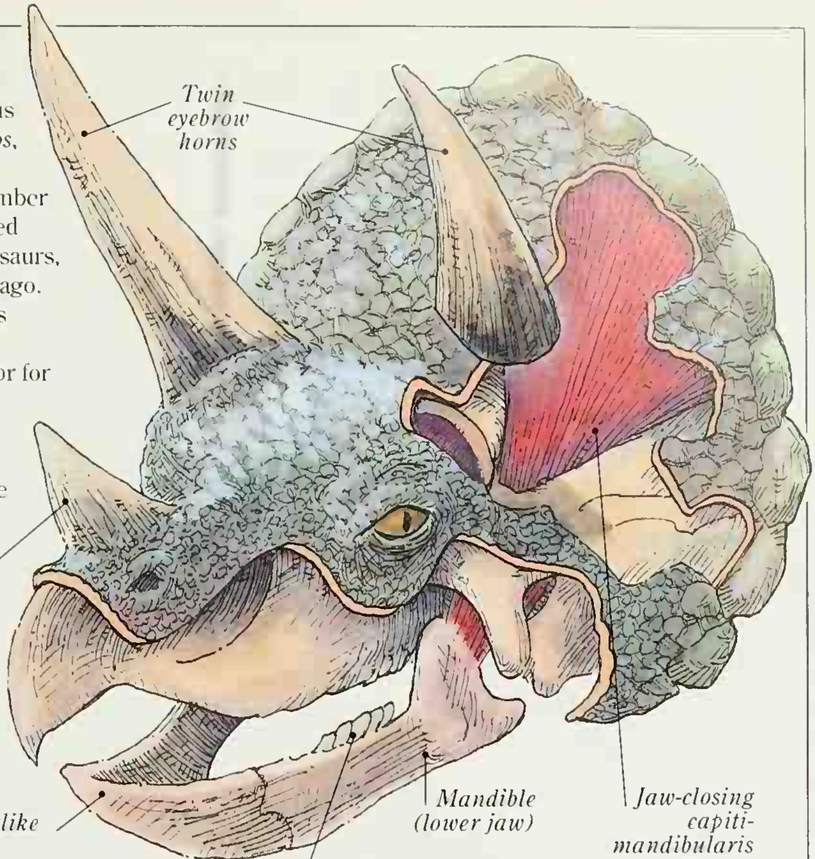
If it gripped the ground with its four-clawed legs, and bent its limbs, *Hylaeosaurus* would stick down like a giant limpet—immovable and impregnable.

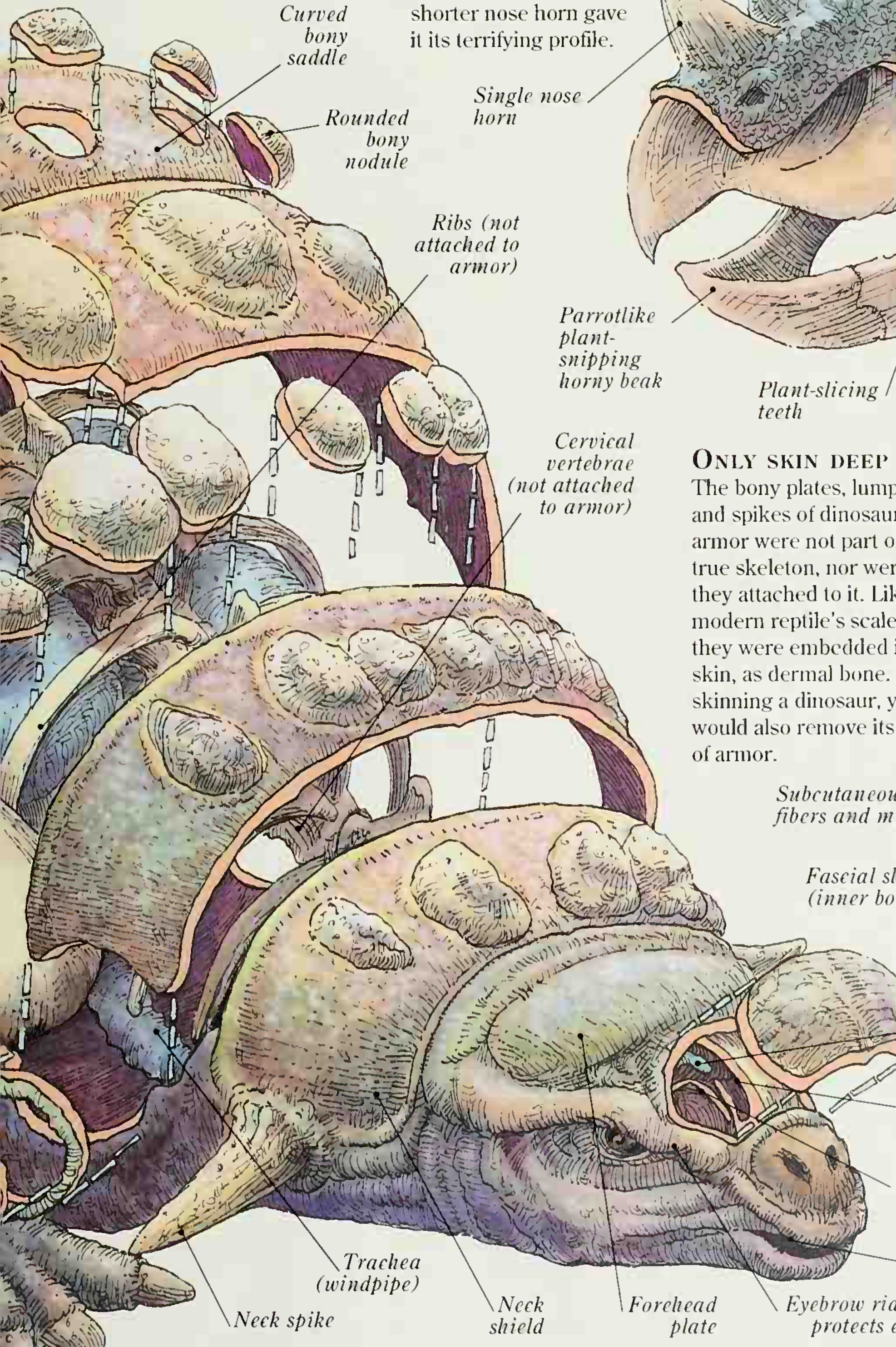
Protection basket

The back of *Hylaeosaurus* had three types of protection. Long, curved plates of bone-reinforced skin curved from side to side like a row of saddles. Within these were embedded rounded lumps or nodules of bone, and sharper bony spikes. The whole structure was like an upturned, armored basket.

Horns and frills

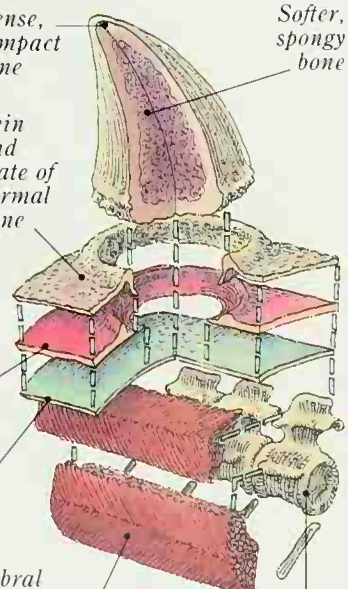
One of the most famous dinosaurs is *Triceratops*, "three-horned face." It was a ceratopsian, member of a group that appeared late in the Age of Dinosaurs, only 100 million years ago. The solid neck frill was probably both a back protector and an anchor for the jaw-closing muscles. Two long eyebrow horns and a shorter nose horn gave it its terrifying profile.





Only skin deep

The bony plates, lumps, and spikes of dinosaur armor were not part of the true skeleton, nor were they attached to it. Like a modern reptile's scales, they were embedded in the skin, as dermal bone. So by skinning a dinosaur, you would also remove its suit of armor.

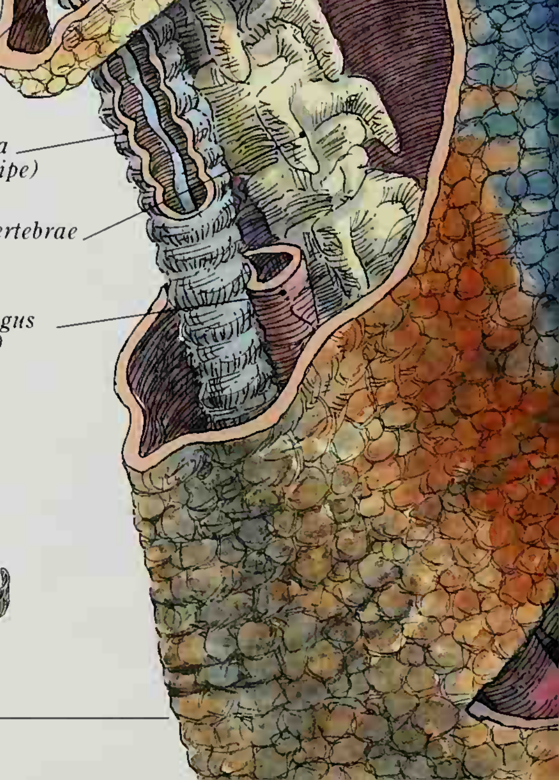


A bite and a breath

Most ankylosaurs seem to have had a bony shelf or plate, the hard palate, between the nose and mouth. This would allow the creature to bite and chew food below the palate, while still being able to breathe through the nasal passages above it. No modern reptiles can do this—but you can.

Holes in the head

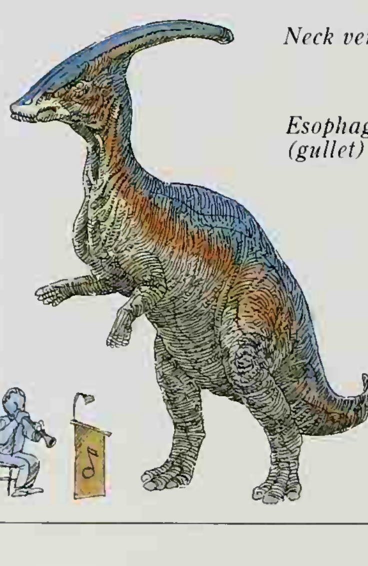
Was prehistory noisy? Reptiles today do not have vocal cords like mammals. The best they can do is a hiss or coarse roar, by blowing air up the windpipe and out through throat, nose, and mouth. However, fossils of one dinosaur group provide intriguing evidence that all was not quiet seventy million years ago. Some of the hadrosaurs possessed strange crests on their heads and long, twisty nasal passages. These odd features may have been living wind instruments—the first big sound systems. The hadrosaurs roared and trumpeted their way through life, but to whom were they singing? Probably one another!

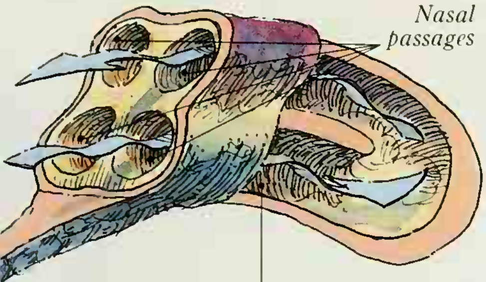



Parasaurolophus may have made a reedy sound like a clarinet

Parasaurolophus

Parasaurolophus was about 32.8 feet (10 meters) long and, like *Edmontosaurus* and *Corythosaurus*, roamed midwestern North America sixty-five to seventy million years ago. The weird headgear of these hadrosaurs may have been brightly colored, to act as a visual signal of status or maturity for other members of the herd. Fossils of female skulls have crests that are much smaller than those of the males.



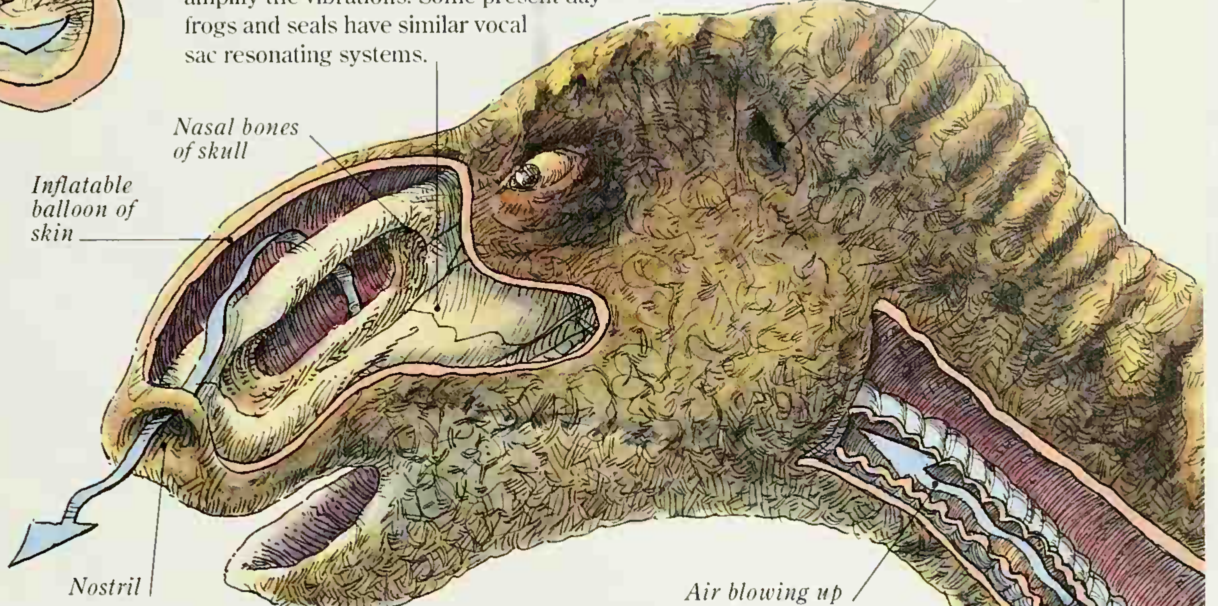


Wind instrument

Parasaurolophus had a very long crest on the rear of its head, which was hollow. Air came up the windpipe, looped back along the lower nasal passage to the rear of the crest, forward along the upper nasal passage, and out through the nostril. By adjusting the airflow, the dinosaur may have made its whole head vibrate.

Blowing its own trumpet

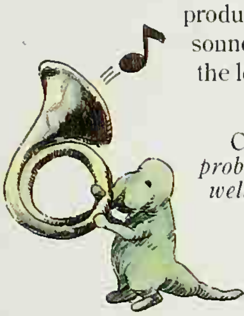
Fossil skulls of *Edmontosaurus* have deep grooves on either side of the nasal area. In life these may have housed loose pouches of skin that could be inflated to balloon out and amplify the vibrations. Some present-day frogs and seals have similar vocal sac resonating systems.



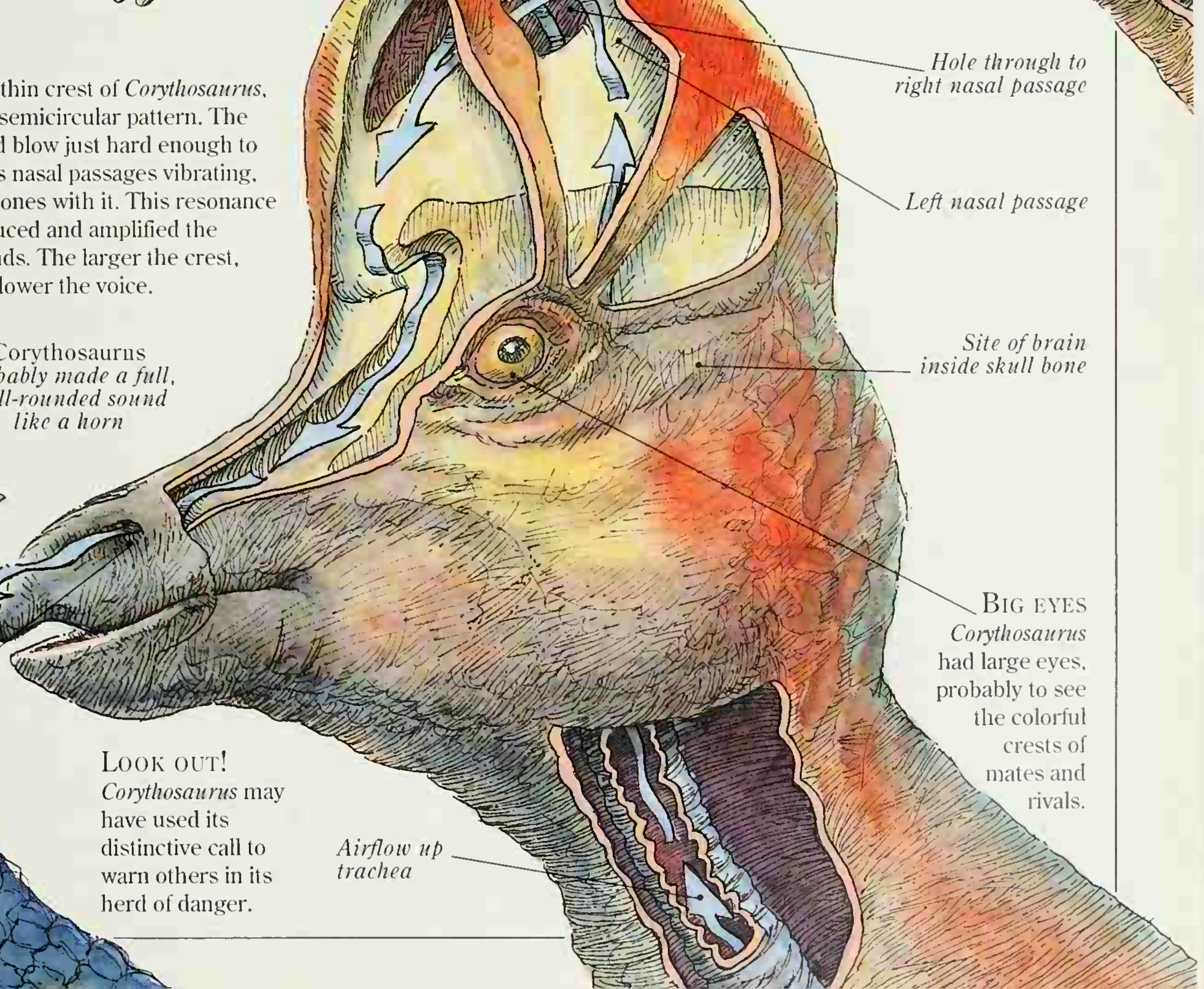
Edmontosaurus *probably made a loud, calling sound like a trumpet*

Plate head

Inside the tall, thin crest of *Corythosaurus*, air flowed in a semicircular pattern. The dinosaur would blow just hard enough to set the air in its nasal passages vibrating, and the skull bones with it. This resonance produced and amplified the sounds. The larger the crest, the lower the voice.



Corythosaurus *probably made a full, well-rounded sound like a horn*

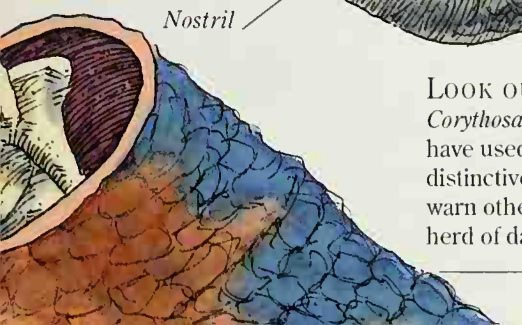


Big eyes

Corythosaurus had large eyes, probably to see the colorful crests of mates and rivals.

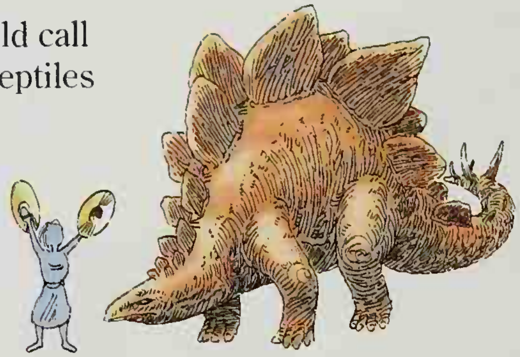
Look out!

Corythosaurus may have used its distinctive call to warn others in its herd of danger.



Brains and bodies

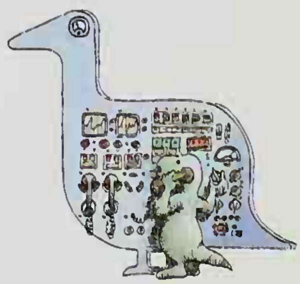
Dinosaurs were probably not what we would call clever or intelligent. Overall, these ancient reptiles had big bodies and small brains, not unlike modern-day crocodiles and lizards. But this does not imply failure. In fact, some may have been alert, fast-reacting, and programmed with a nerve system library of instincts and reflexes that enabled them to survive for so long. *Stegosaurus* had a very small brain indeed, yet its kind spread over a wide area and survived for millions of years.



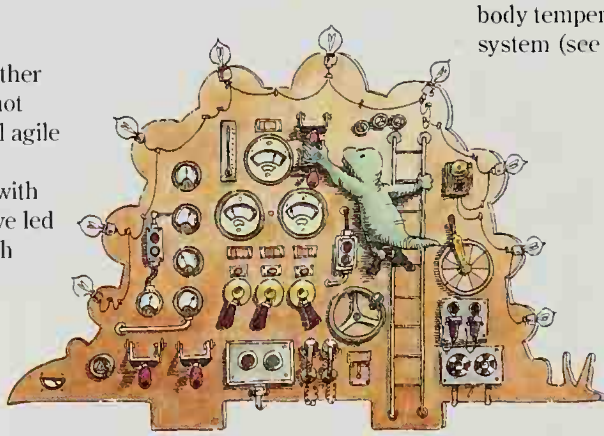
Stegosaurus

Stegosaurus is the most famous small-brain dinosaur. This armored mound of flesh and bone, weighing in at 1.18 tons (1.5 tonnes), and measuring more than 23 feet (7 meters) long, was controlled by a lump of nerves the size of a hen's egg.

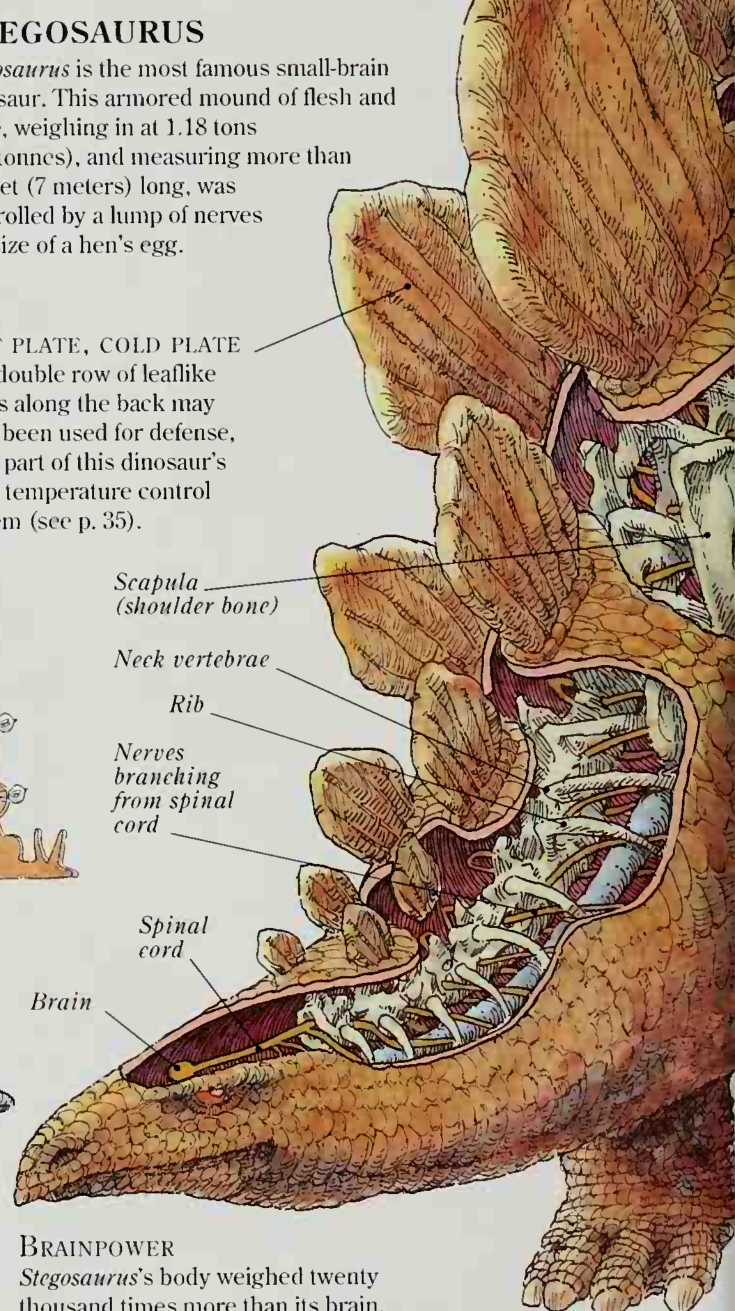
Bright spark...
Stenonychosaurus had a relatively large brain in a smallish body. This meant it probably had good control over body movements, fine coordination skills, sharp senses, and even capacity left over for a simple memory bank.



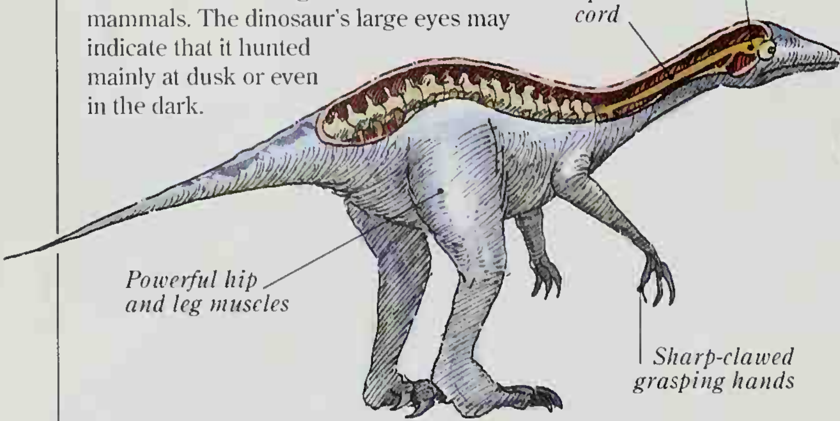
...Dim bulb?
Stegosaurus, on the other hand, was probably not capable of skilled and agile movements. Limited brainpower coupled with sheer bulk would have led to slow reactions, with much of the body "running on automatic."



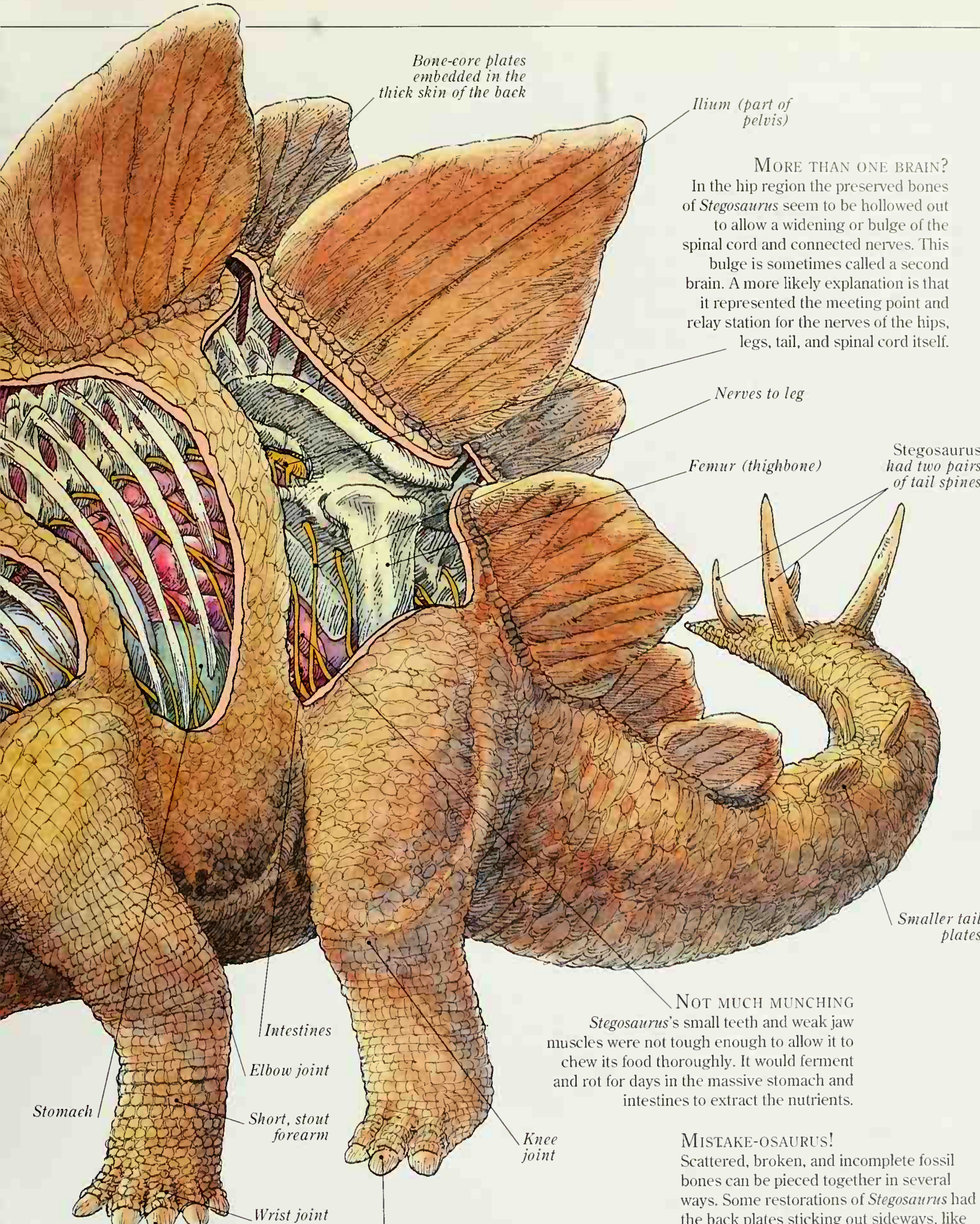
Hot plate, cold plate
The double row of leaflike plates along the back may have been used for defense, or as part of this dinosaur's body temperature control system (see p. 35).



Small and sprightly
Stenonychosaurus was 6.5 feet (2 meters) long and had fast reflexes, which it would have used for hunting lizards and small mammals. The dinosaur's large eyes may indicate that it hunted mainly at dusk or even in the dark.



Brainpower
Stegosaurus's body weighed twenty thousand times more than its brain. *Stenonychosaurus*'s body was five hundred times heavier than its brain. Your body is only fifty times heavier than your brain, indicating that your nervous system is highly efficient by comparison.



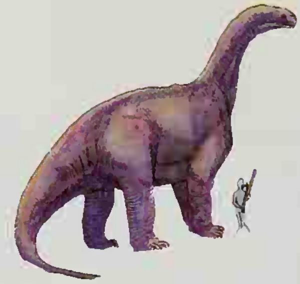
MORE THAN ONE BRAIN?
In the hip region the preserved bones of *Stegosaurus* seem to be hollowed out to allow a widening or bulge of the spinal cord and connected nerves. This bulge is sometimes called a second brain. A more likely explanation is that it represented the meeting point and relay station for the nerves of the hips, legs, tail, and spinal cord itself.

NOT MUCH MUNCHING
Stegosaurus's small teeth and weak jaw muscles were not tough enough to allow it to chew its food thoroughly. It would ferment and rot for days in the massive stomach and intestines to extract the nutrients.

MISTAKE-OSAURUS!
Scattered, broken, and incomplete fossil bones can be pieced together in several ways. Some restorations of *Stegosaurus* had the back plates sticking out sideways, like tiles on a roof (the name means "roofed reptile"). Others have the plates in neat pairs, not staggered. Some early versions had four pairs of tail spines, not two.

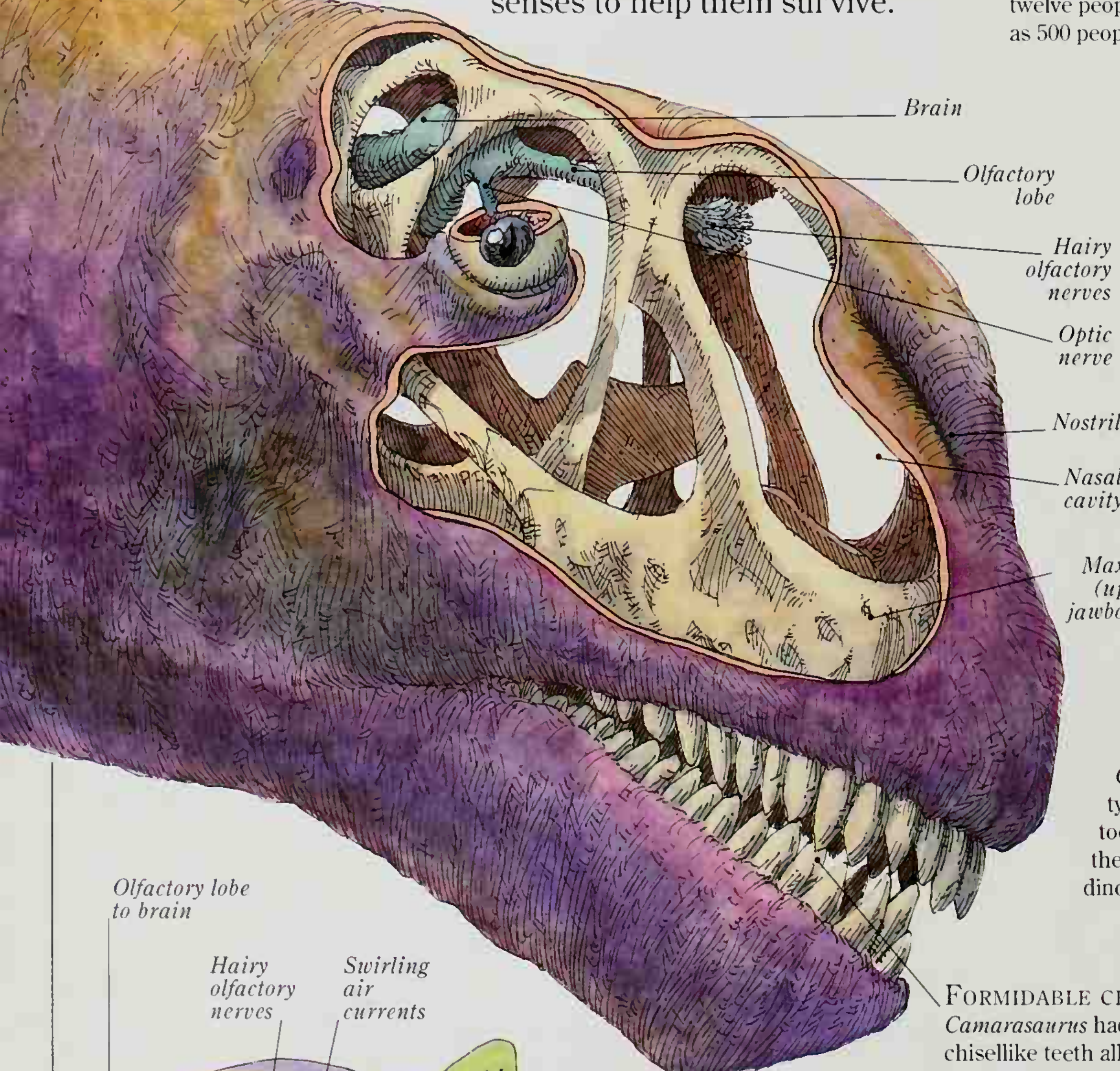
Sensitive dinosaurs

After the squishy dinosaur brain rots away, a fossil called an endocast can form to fill the hollows in the skull. This is not quite a brain cast, since a living brain is surrounded by protective tissue and fluid. But there is sufficient similarity to show that dinosaurs had a general brain organization very like that of today's reptiles. Dinosaur endocasts also reveal chambers for the sense organs such as eyes, ears, and especially the nose, as seen in *Camarasaurus*. Far from being stupid, dinosaurs used sharp senses to help them survive.



Camarasaurus

A sauropod relation of *Brachiosaurus* and *Diplodocus*, *Camarasaurus* was an inhabitant of western North America about 140 million years ago. It was as tall as five people standing on each other's heads, as long as twelve people lying end to end, and as heavy as 500 people just sitting there.



Big nose

Camarasaurus's skull consisted mainly of bony struts forming a large, airy chamber at the front, the nasal cavity. The nostrils were probably large and set high on the head. This gave ample space for copious amounts of aroma-bearing air to waft to and fro, on the way in and out of the lungs.

A washed-up idea

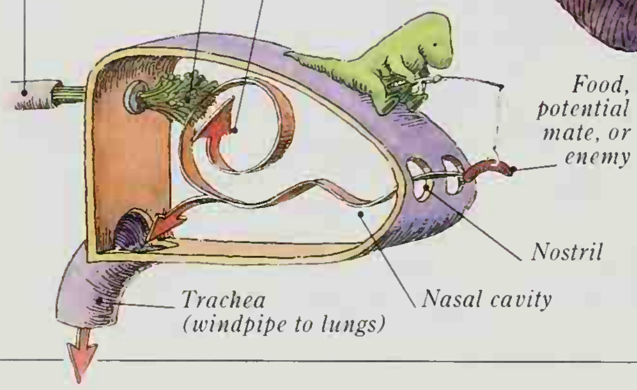
Experts once thought sauropods lived underwater, using their long necks and high nostrils as snorkels. But fossils of sauropod footprints made in shallow water indicate otherwise.

Duck-bill dino

Corythosaurus had the typical horny, toothless beak of the duck-billed dinosaurs.

Formidable choppers

Camarasaurus had large, deep-rooted, chisellike teeth all around its jaws. It probably reached up to the treetops with its long, flexible neck to chop off the leaves and twigs there.



Sniff 'n' smell

In a modern reptile, the olfactory organ bears tufts of small hairs that project into the nasal cavity. Odorous substances inhaled with each sniff settle on the hairs and stimulate nerve signals. These are relayed to the olfactory center of the brain, where smells are identified.

Big eyes

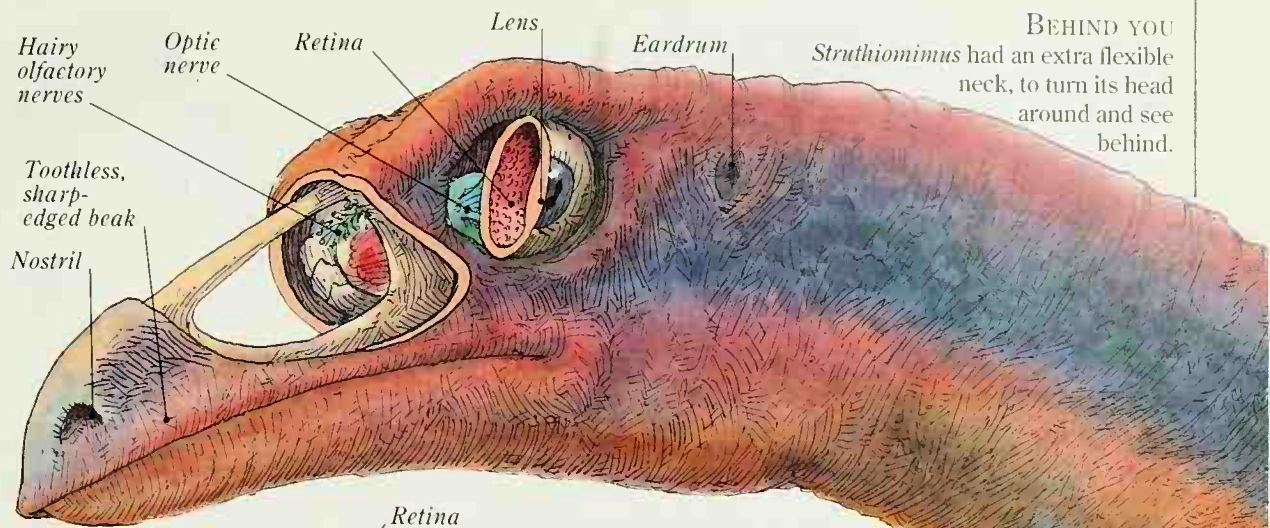
The eye sockets of *Struthiomimus*, the "ostrich mimic," were proportionally huge. Its endocast indicates that its brain was big, too. This points to a nimble, quick-reacting animal that relied on its eyes for hunting insects, lizards, and other prey, and for spotting enemies.

Bending beak

Struthiomimus's skull bones were light and thin, enabling its birdlike, toothless beak to move with great flexibility.

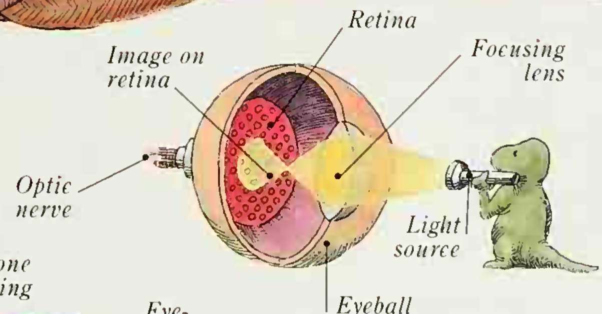
Behind you

Struthiomimus had an extra flexible neck, to turn its head around and see behind.



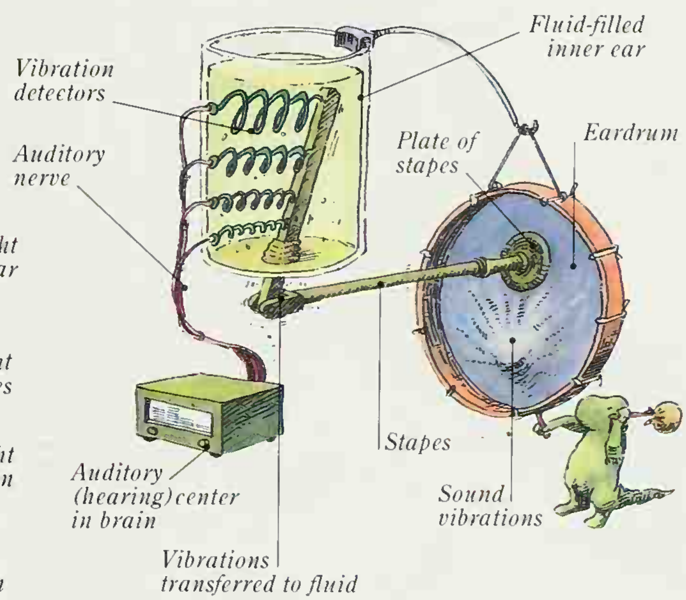
Stare 'n' see

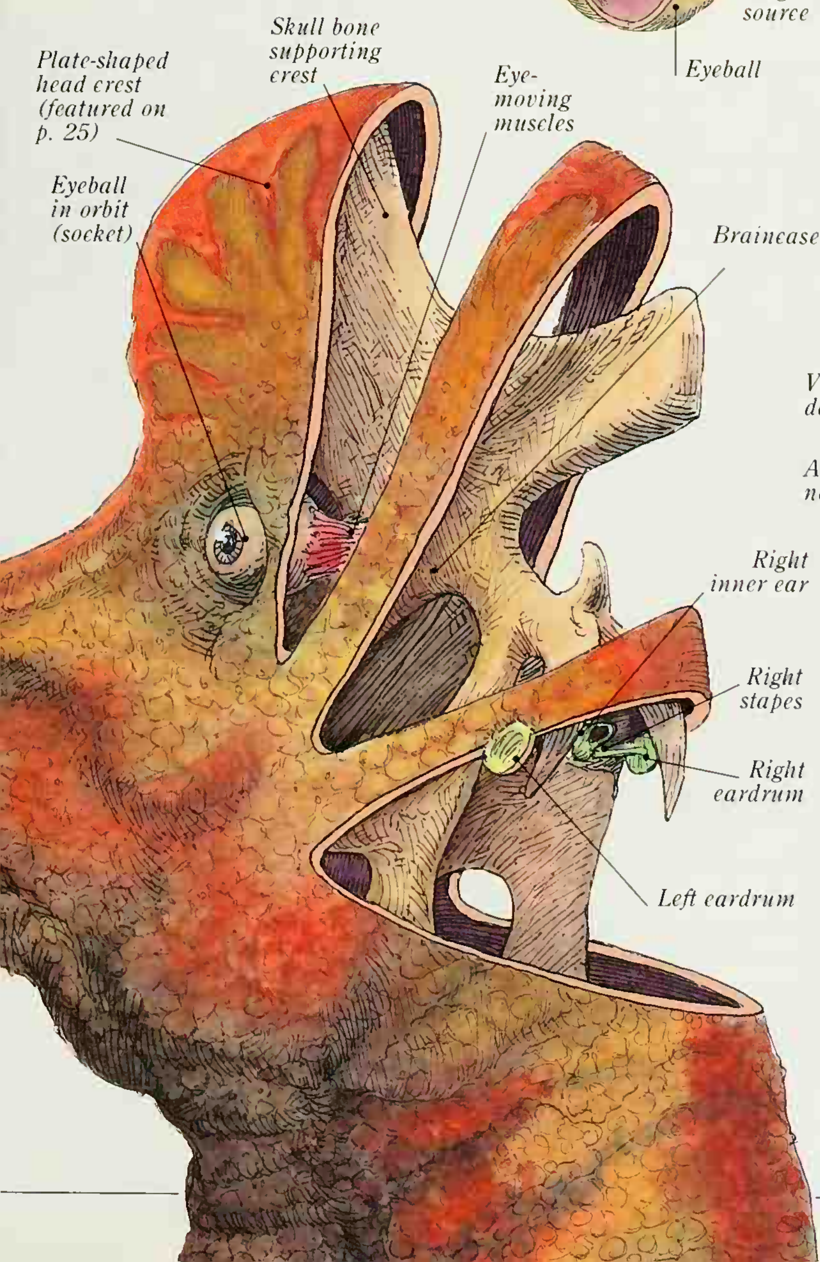
Reptile eyes are similar in basic design to our own. The lens focuses light rays onto the eyeball's inner lining, the retina. Light-sensitive cells in the retina turn the pattern of rays into nerve signals and send them along the optic nerve to the brain's optic lobes, for interpretation.



Hear 'n' there

Airborne sound waves hit the eardrum or tympanic membrane, making it vibrate. This moves the piston-like stapes bone, which sets up vibrations in the fluid-filled inner ear. Delicate cells in the fluid transform the vibrations into nerve signals that pass along the auditory nerve to the brain's hearing center.



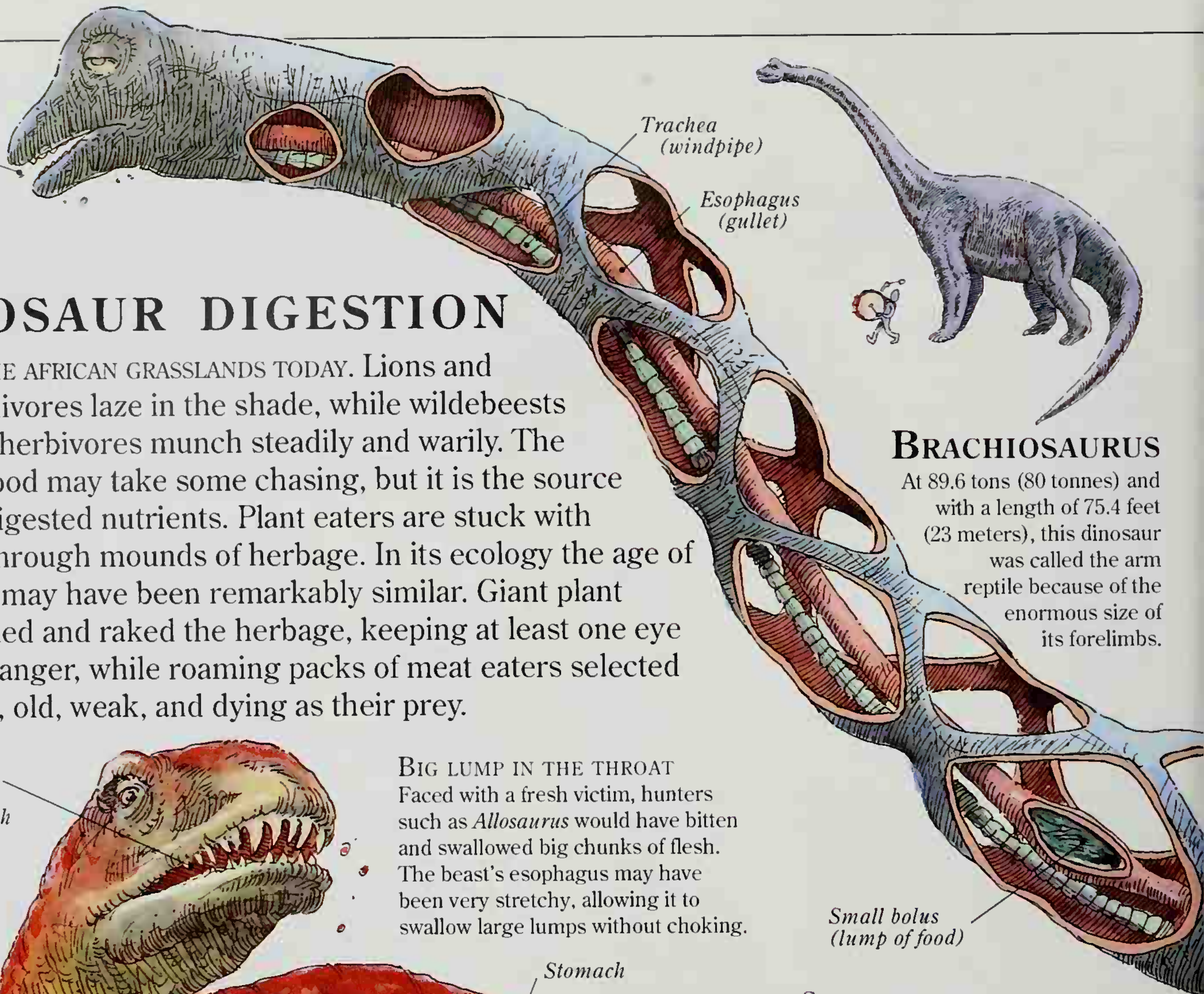


Big ears

If *Corythosaurus* could call to its herd (see p. 25), it must have been able to hear a response. The supporting evidence includes fossil finds of the small, rod-shaped stapes, and a pit or depression in the skull bone that was almost certainly occupied by the ear drum. Remnants of the stapes, and even the shape of the inner ear, have been found in several types of dinosaur.

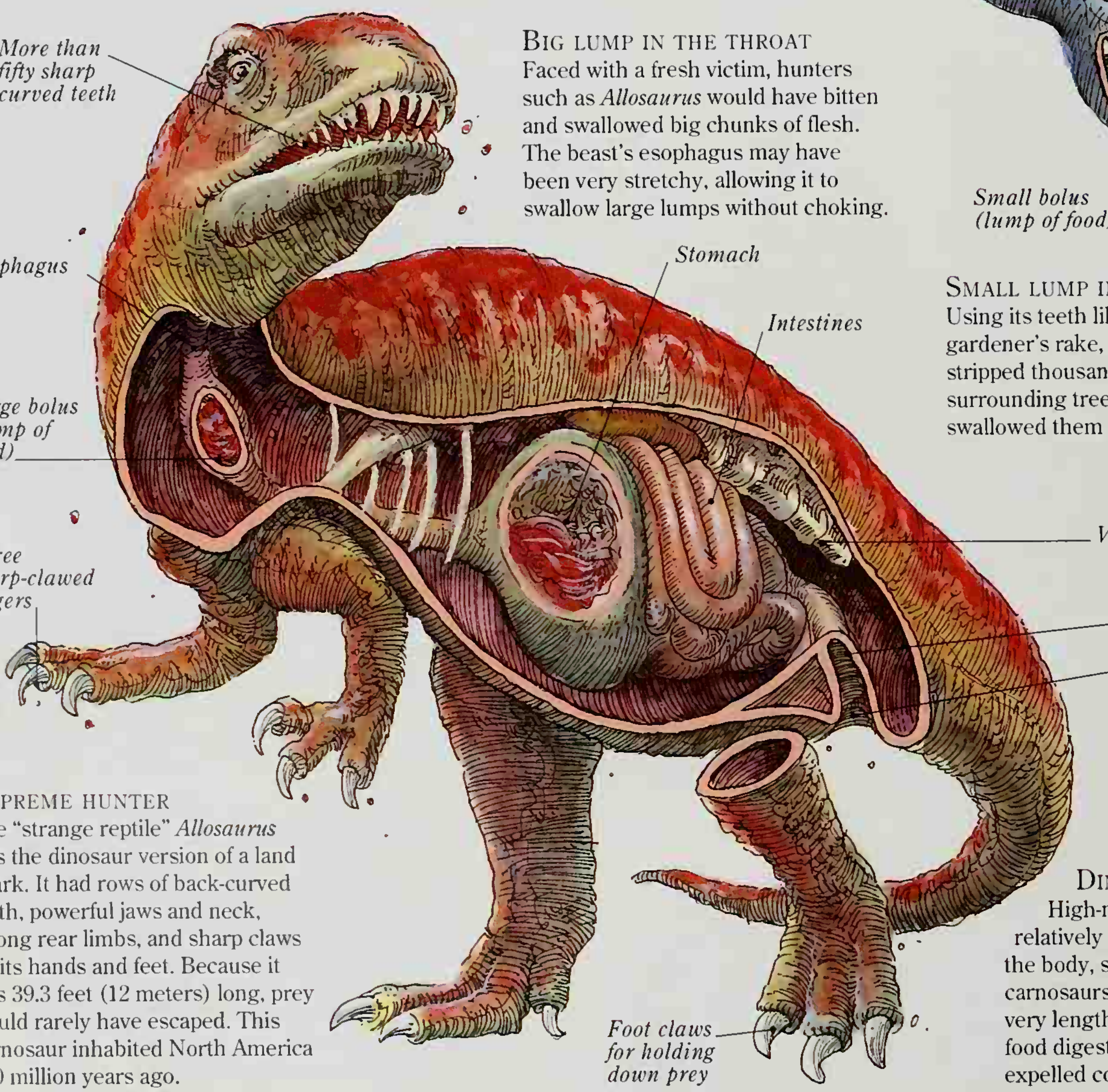
DINOSAUR DIGESTION

LOOK AT THE AFRICAN GRASSLANDS TODAY. Lions and other carnivores laze in the shade, while wildebeests and other herbivores munch steadily and warily. The hunter's food may take some chasing, but it is the source of easily digested nutrients. Plant eaters are stuck with chewing through mounds of herbage. In its ecology the age of dinosaurs may have been remarkably similar. Giant plant eaters pulled and raked the herbage, keeping at least one eye open for danger, while roaming packs of meat eaters selected the young, old, weak, and dying as their prey.



BRACHIOSAURUS

At 89.6 tons (80 tonnes) and with a length of 75.4 feet (23 meters), this dinosaur was called the arm reptile because of the enormous size of its forelimbs.



BIG LUMP IN THE THROAT
Faced with a fresh victim, hunters such as *Allosaurus* would have bitten and swallowed big chunks of flesh. The beast's esophagus may have been very stretchy, allowing it to swallow large lumps without choking.

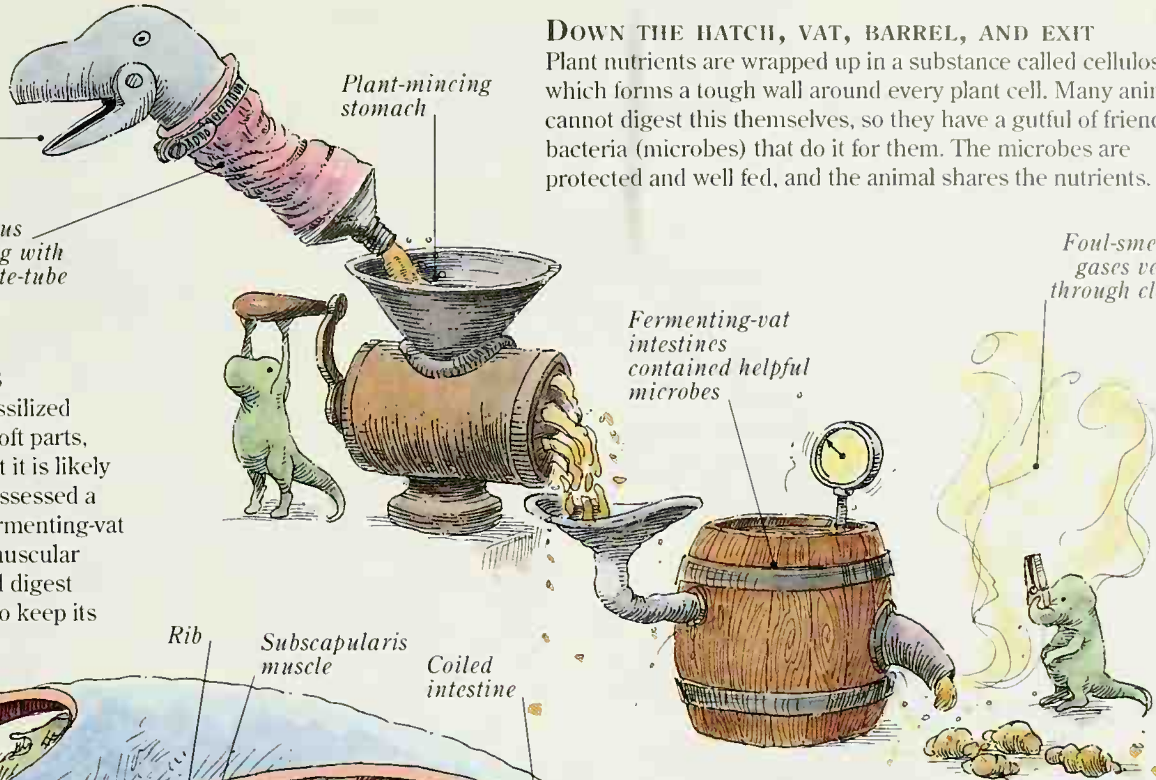
SMALL LUMP IN THE THROAT
Using its teeth like the prongs of a gardener's rake, *Brachiosaurus* stripped thousands of leaves from the surrounding trees and bushes and swallowed them in small batches.

SUPREME HUNTER
The "strange reptile" *Allosaurus* was the dinosaur version of a land shark. It had rows of back-curved teeth, powerful jaws and neck, strong rear limbs, and sharp claws on its hands and feet. Because it was 39.3 feet (12 meters) long, prey would rarely have escaped. This carnosaur inhabited North America 140 million years ago.

DINO DUNG
High-nutrition food is relatively easy to absorb into the body, so the intestines of carnosaurs may not have been very lengthy. With most of the food digested, they probably expelled compact droppings.

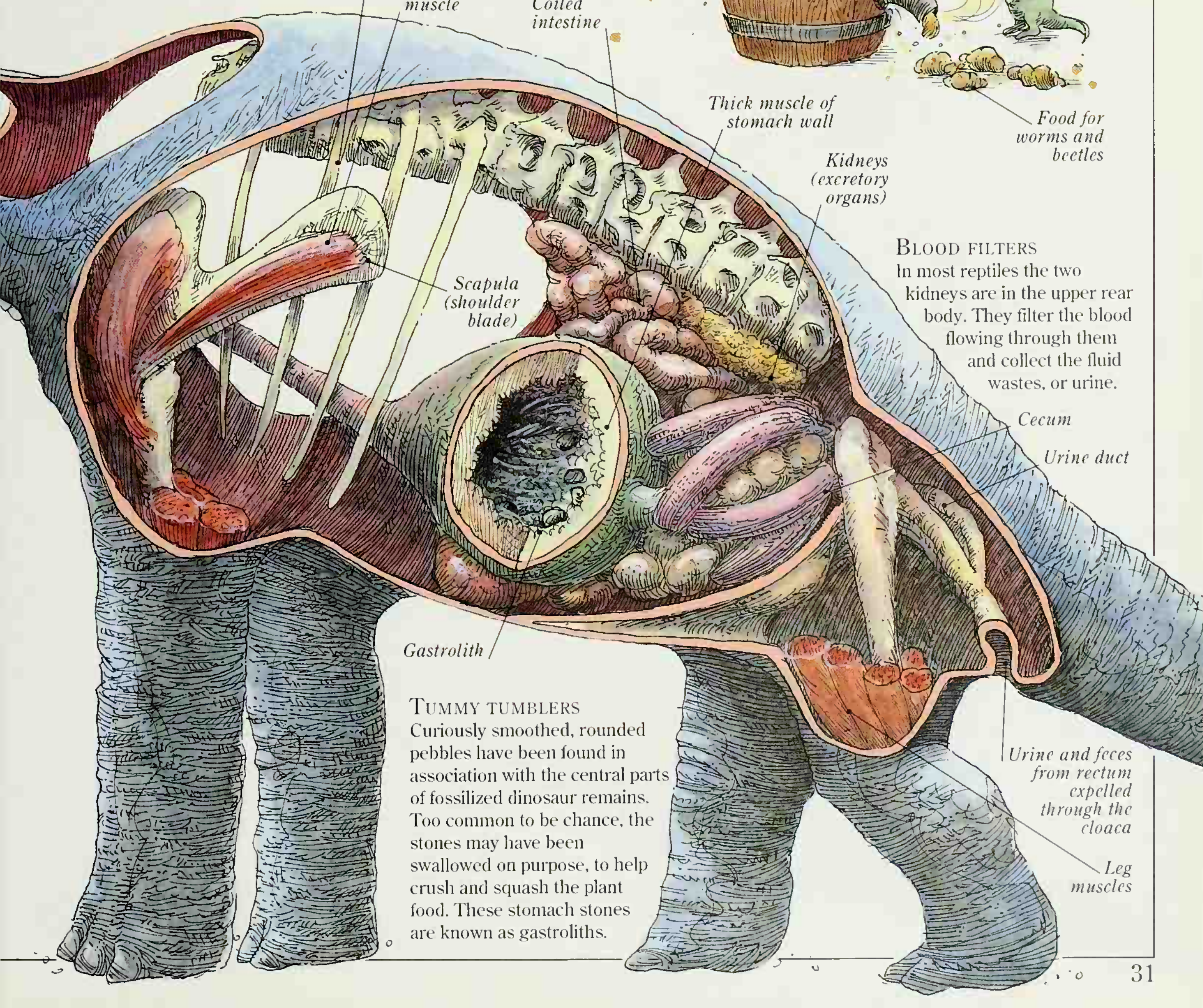
Down the hatch, vat, barrel, and exit

Plant nutrients are wrapped up in a substance called cellulose, which forms a tough wall around every plant cell. Many animals cannot digest this themselves, so they have a gutful of friendly bacteria (microbes) that do it for them. The microbes are protected and well fed, and the animal shares the nutrients.



All that remains

There are very few fossilized remains of dinosaur soft parts, such as stomachs. But it is likely that *Brachiosaurus* possessed a space capsule–size fermenting-vat stomach with thick, muscular walls, able to hold and digest enough plant matter to keep its enormous body fed.



Blood filters

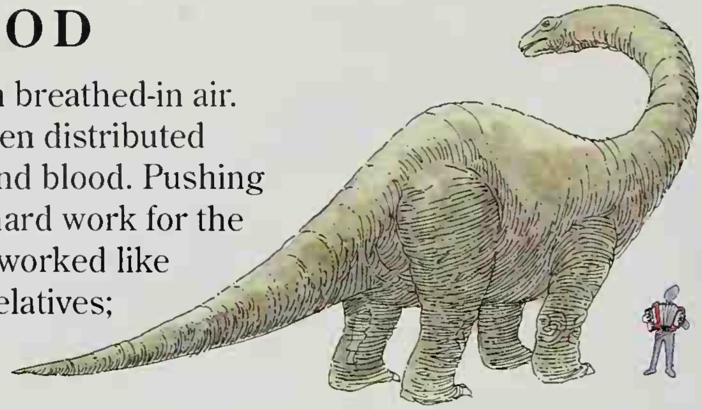
In most reptiles the two kidneys are in the upper rear body. They filter the blood flowing through them and collect the fluid wastes, or urine.

Tummy tumblers

Curiously smoothed, rounded pebbles have been found in association with the central parts of fossilized dinosaur remains. Too common to be chance, the stones may have been swallowed on purpose, to help crush and squash the plant food. These stomach stones are known as gastroliths.

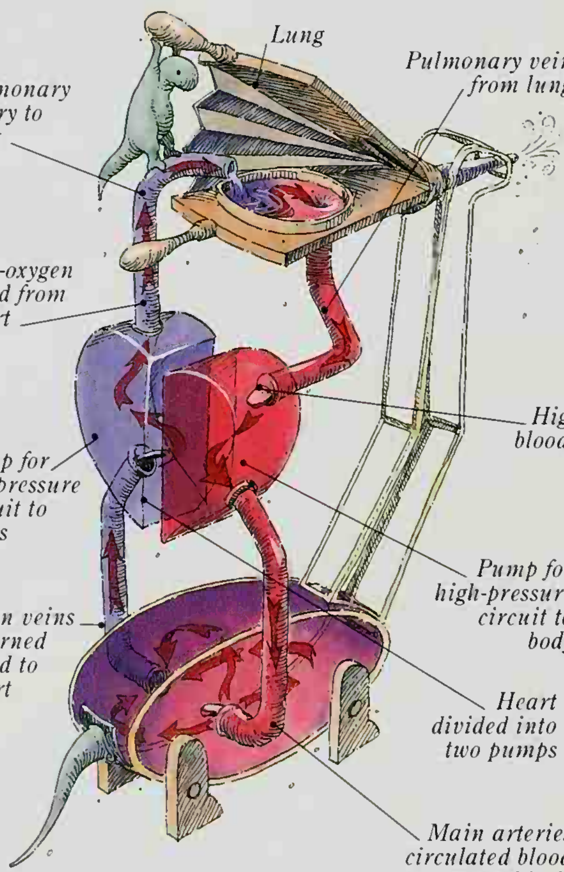
BREATHING AND BLOOD

A DINOSAUR'S OXYGEN SUPPLY probably came from breathed-in air. Two lungs absorbed the oxygen, which was then distributed around the body by the heart, blood vessels, and blood. Pushing blood around a body bigger than a truck was hard work for the heart of *Apatosaurus*. Its heart could not have worked like the partly divided heart of some of its reptile relatives; otherwise the same immense pressure needed to push blood up to its brain would have forced blood into its delicate lungs and blown them apart. The heart must have been fully divided into two separate pumps, one powering a high-pressure circuit to the body, the other a low-pressure circuit to the lungs.



APATOSAURUS

This massive beast was 68.8 feet (21 meters) nose to tail, was 16.4 feet (5 meters) high at its hips, and weighed 33.6 tons (30 tonnes). Some of its fossils were once named *Brontosaurus*, but all specimens are now called *Apatosaurus*, or "deceptive reptile"—a good name for a dinosaur that confused the experts.



AIR TO BLOOD TO BODY

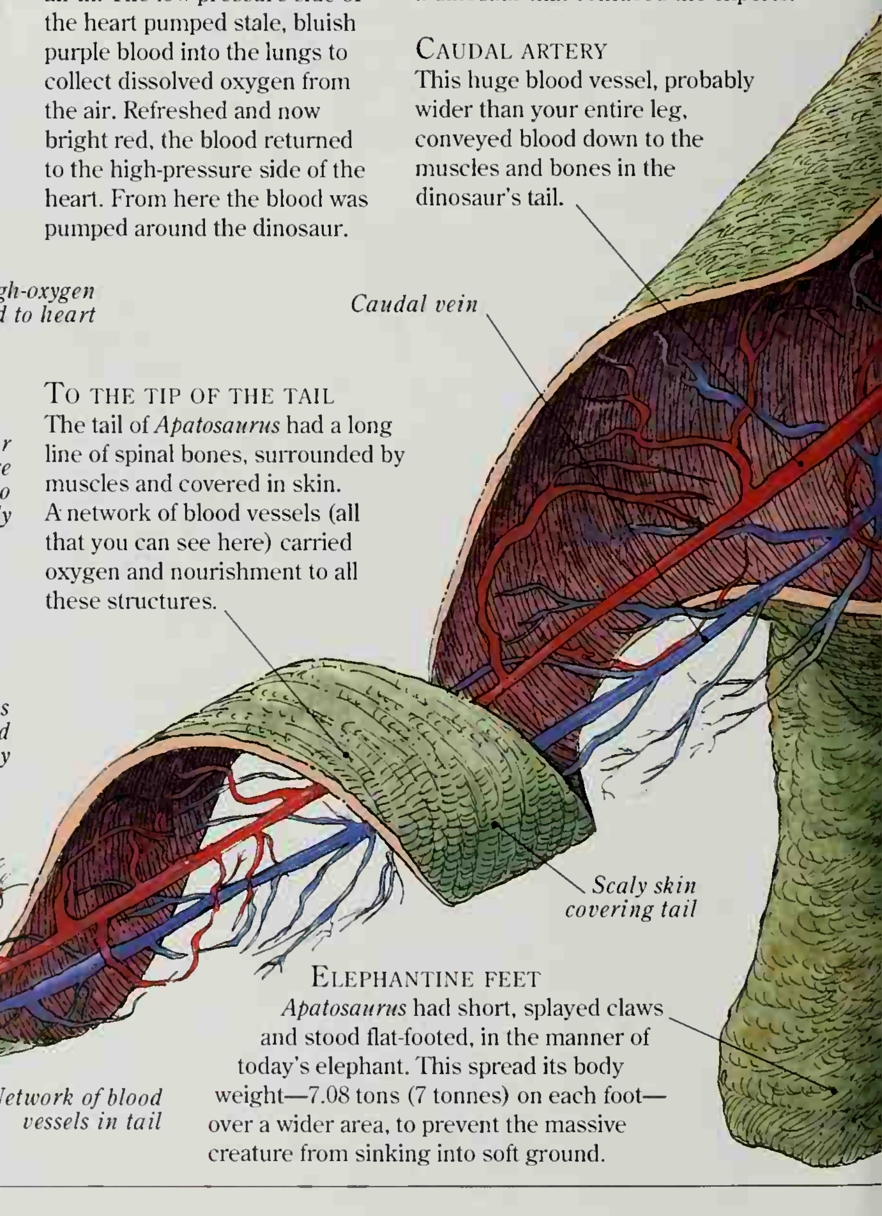
The dinosaur's lungs expanded like bellows and sucked fresh air in. The low-pressure side of the heart pumped stale, bluish purple blood into the lungs to collect dissolved oxygen from the air. Refreshed and now bright red, the blood returned to the high-pressure side of the heart. From here the blood was pumped around the dinosaur.

CAUDAL ARTERY

This huge blood vessel, probably wider than your entire leg, conveyed blood down to the muscles and bones in the dinosaur's tail.

TO THE TIP OF THE TAIL

The tail of *Apatosaurus* had a long line of spinal bones, surrounded by muscles and covered in skin. A network of blood vessels (all that you can see here) carried oxygen and nourishment to all these structures.

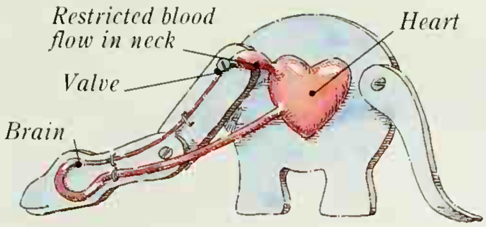


BRINGING UP THE REAR

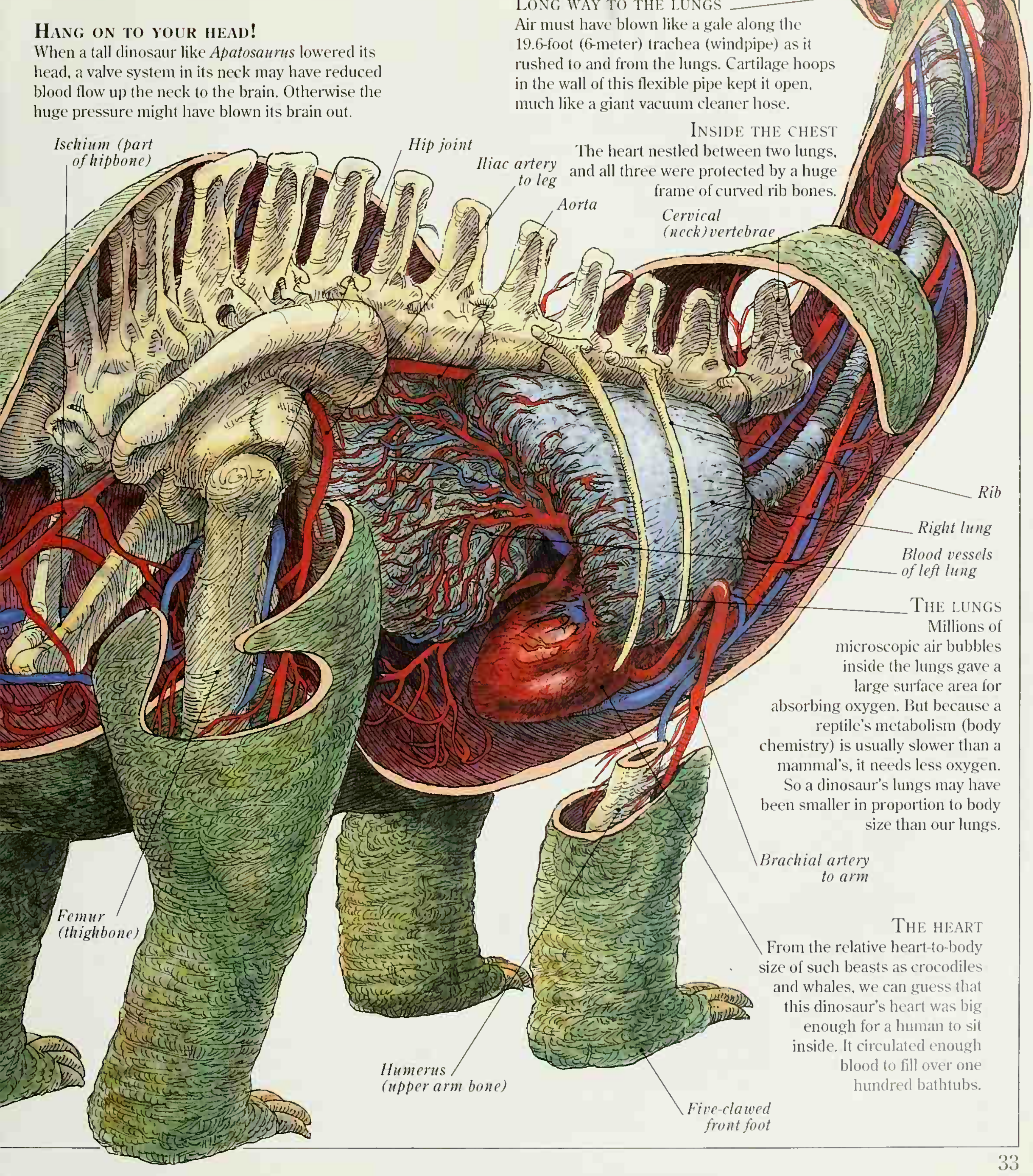
When a dinosaur fought off predators by whipping its tail at them, the blood flow increased to supply the active tail muscles.

ELEPHANTINE FEET

Apatosaurus had short, splayed claws and stood flat-footed, in the manner of today's elephant. This spread its body weight—7.08 tons (7 tonnes) on each foot—over a wider area, to prevent the massive creature from sinking into soft ground.



HANG ON TO YOUR HEAD!
When a tall dinosaur like *Apatosaurus* lowered its head, a valve system in its neck may have reduced blood flow up the neck to the brain. Otherwise the huge pressure might have blown its brain out.



LONG WAY TO THE LUNGS
Air must have blown like a gale along the 19.6-foot (6-meter) trachea (windpipe) as it rushed to and from the lungs. Cartilage hoops in the wall of this flexible pipe kept it open, much like a giant vacuum cleaner hose.

INSIDE THE CHEST
The heart nestled between two lungs, and all three were protected by a huge frame of curved rib bones.

THE LUNGS
Millions of microscopic air bubbles inside the lungs gave a large surface area for absorbing oxygen. But because a reptile's metabolism (body chemistry) is usually slower than a mammal's, it needs less oxygen. So a dinosaur's lungs may have been smaller in proportion to body size than our lungs.

THE HEART
From the relative heart-to-body size of such beasts as crocodiles and whales, we can guess that this dinosaur's heart was big enough for a human to sit inside. It circulated enough blood to fill over one hundred bathtubs.

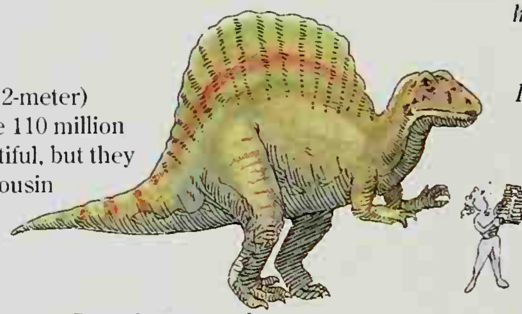
A HEATED DEBATE

MODERN REPTILES ARE COLD-BLOODED. Dinosaurs were reptiles. But were dinosaurs cold-blooded? Probably, but some experts are warming to other ideas. It is likely that most dinosaurs were cold-blooded, or ectothermic, meaning "warmth from without." An ectotherm's body temperature depends on its surroundings. In hot weather it warms up, ready for action. In cold conditions it becomes slow and sluggish. However, many of today's reptiles can regulate their body temperature within certain limits by behavioral methods—basking in the sun or cooling off in the shade. Maybe dinosaurs did the same or, like *Spinosaurus*, kept a secret in their sails.

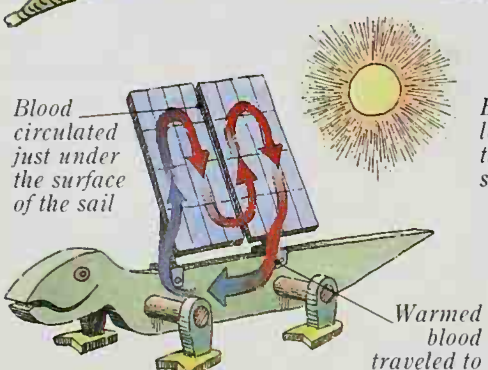
RAISING THE SAIL
Spinosaurus's huge back sail was supported by flattened bony planks. These are the enlarged dorsal processes projecting from the vertebrae (backbones). Some of these planks are almost 6.6 feet (2 meters) long—as tall as a tall adult!

SPINOSAURUS

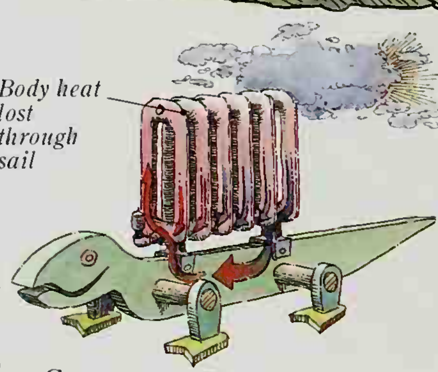
This powerfully built, 39.4-foot (12-meter) carnivore dwelled in Africa, some 110 million years ago. Its fossils are not plentiful, but they indicate that it was a carnosaur cousin of the supreme North American hunter *Allosaurus* (see p. 30).



CENTRAL HEATING
As described above, reptiles and many other creatures—from insects to sharks—are ectothermic. Birds and mammals are endothermic, meaning "warmth from within." They generate their own body heat through metabolism. These are the chemical processes that keep an animal's body working.



WARMING UP
Spinosaurus's extravagant sail may have helped regulate its body temperature by acting as a heat exchanger. To warm itself rapidly, the beast stood sideways to the sun, and its sail soaked up the rays like a solar panel.



COOLING DOWN
If its body became too warm, *Spinosaurus* could stand in the open, breezy shade. The sail worked as a radiator. Blood drew heat from the body, flowed through the sail, and radiated the warmth to the passing air.

RISE AND SHINE
Spinosaurus's temperature control mechanism may have given it an edge over competitors, allowing it to get up and go in the early-morning sun before other cold-blooded creatures—including its prey—shook off the cool of the night.

STEP ON IT
Spinosaurus had strong, pillarlike back legs. The huge claws on its feet may have been used to hold down its struggling prey while the dinosaur's mouth tore off chunks of flesh.

Blood branches

Vertebral blood vessels probably branched between the skin and the supporting bone of the sail to give a large surface area for heat exchange.

Roughneck

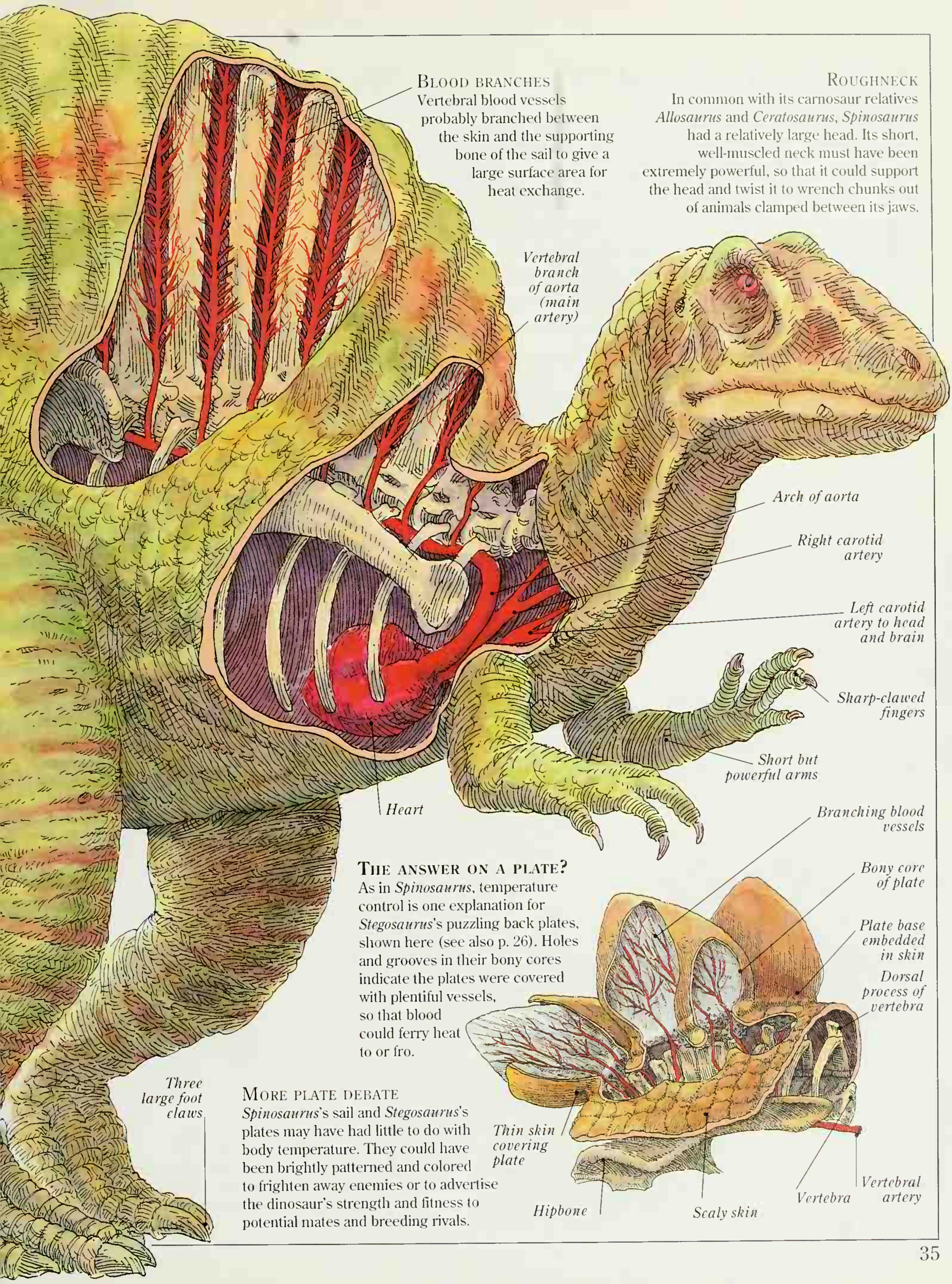
In common with its carnosaur relatives *Allosaurus* and *Ceratosaurus*, *Spinosaurus* had a relatively large head. Its short, well-muscled neck must have been extremely powerful, so that it could support the head and twist it to wrench chunks out of animals clamped between its jaws.

The answer on a plate?

As in *Spinosaurus*, temperature control is one explanation for *Stegosaurus*'s puzzling back plates, shown here (see also p. 26). Holes and grooves in their bony cores indicate the plates were covered with plentiful vessels, so that blood could ferry heat to or fro.

More plate debate

Spinosaurus's sail and *Stegosaurus*'s plates may have had little to do with body temperature. They could have been brightly patterned and colored to frighten away enemies or to advertise the dinosaur's strength and fitness to potential mates and breeding rivals.



EGGS AND BABIES

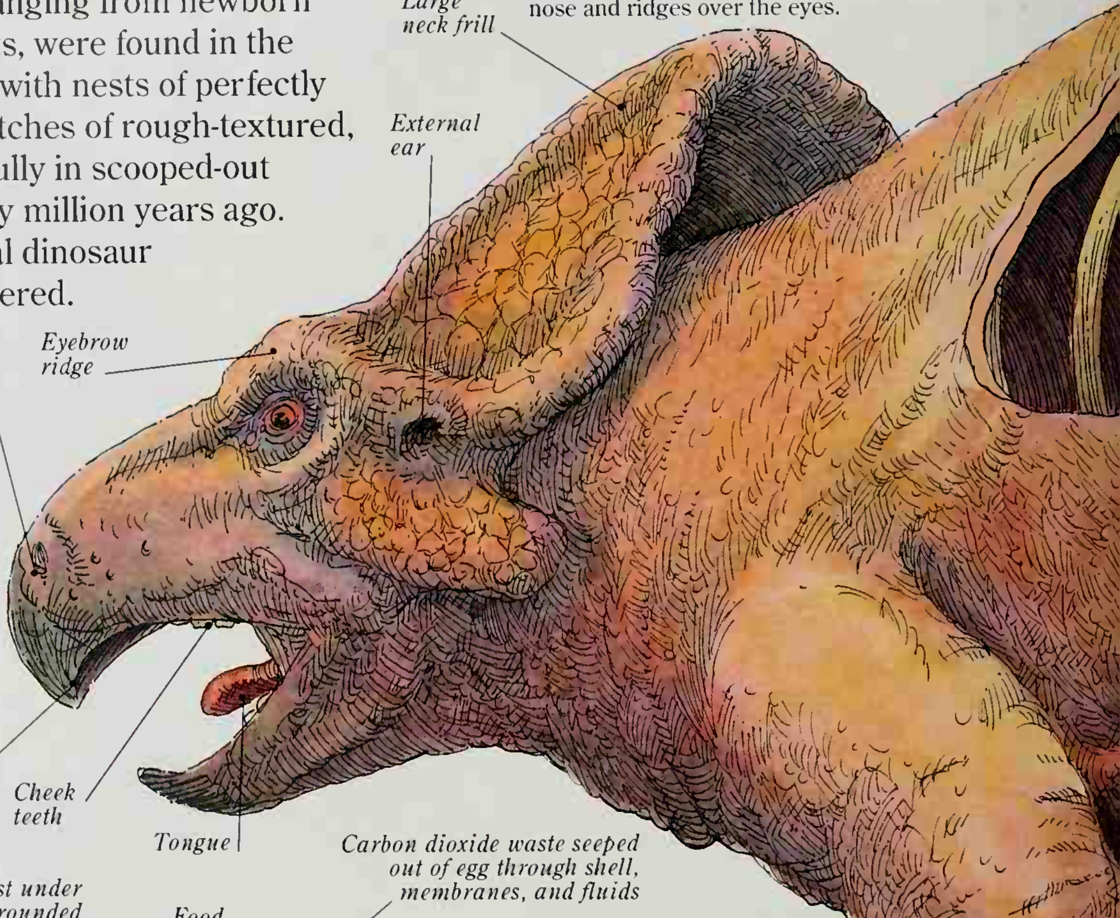
DID DINOSAURS LAY EGGS, as their living reptile relatives do? Firm fossil evidence was unearthed in the 1920s in Mongolia's Gobi Desert. Here numerous stony skeletons of the small horned dinosaur *Protoceratops*, ranging from newborn babies to full-grown adults, were found in the sandstone layers—along with nests of perfectly fossilized eggs. These batches of rough-textured, oval eggs were laid carefully in scooped-out hollows in the sand eighty million years ago. Since then eggs of several dinosaur species have been discovered.

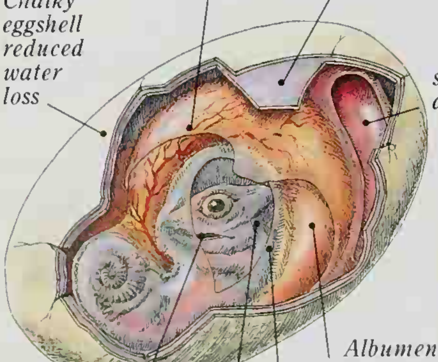
FIRST FRILLS

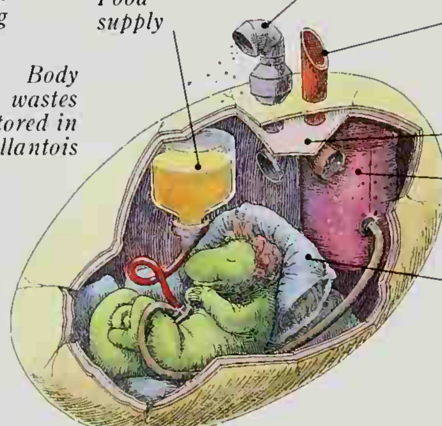
Protoceratops ("first horned face") was a forerunner of the ceratopsian, or horned dinosaur, group, which includes *Triceratops* with its huge neck frill. *Protoceratops*'s frill was already quite large, but the facial horns that give the group its name were only just beginning to evolve, perhaps as a bump on the nose and ridges over the eyes.

SNACK SNIPPERS

Protoceratops was probably a herbivoire. The front of its mouth was tipped with a sharp, beak-shaped horn, for snipping up leaves and stems. Powerful jaw muscles worked scissorlike tooth batteries that cut tough plants into pieces. These were swallowed whole, since the teeth were of no use for chewing.







INSIDE THE EGG(S)

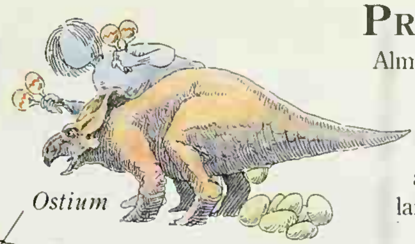
Amphibians lay their soft, jelly-covered eggs in water; they could not survive elsewhere. A reptile egg, with its protective shell, was a great step forward to life on land. The developing baby fed on its yummy yolk in a private pool surrounded by three membranes—from inside out, the amnion, allantois, and chorion. Can you spot the parallels between the real egg and the fully fitted reptile nursery?

FOUR-FOOTED GAIT

Protoceratops almost certainly moved on all fours, supporting its massive weight on its short front and longer rear limbs.

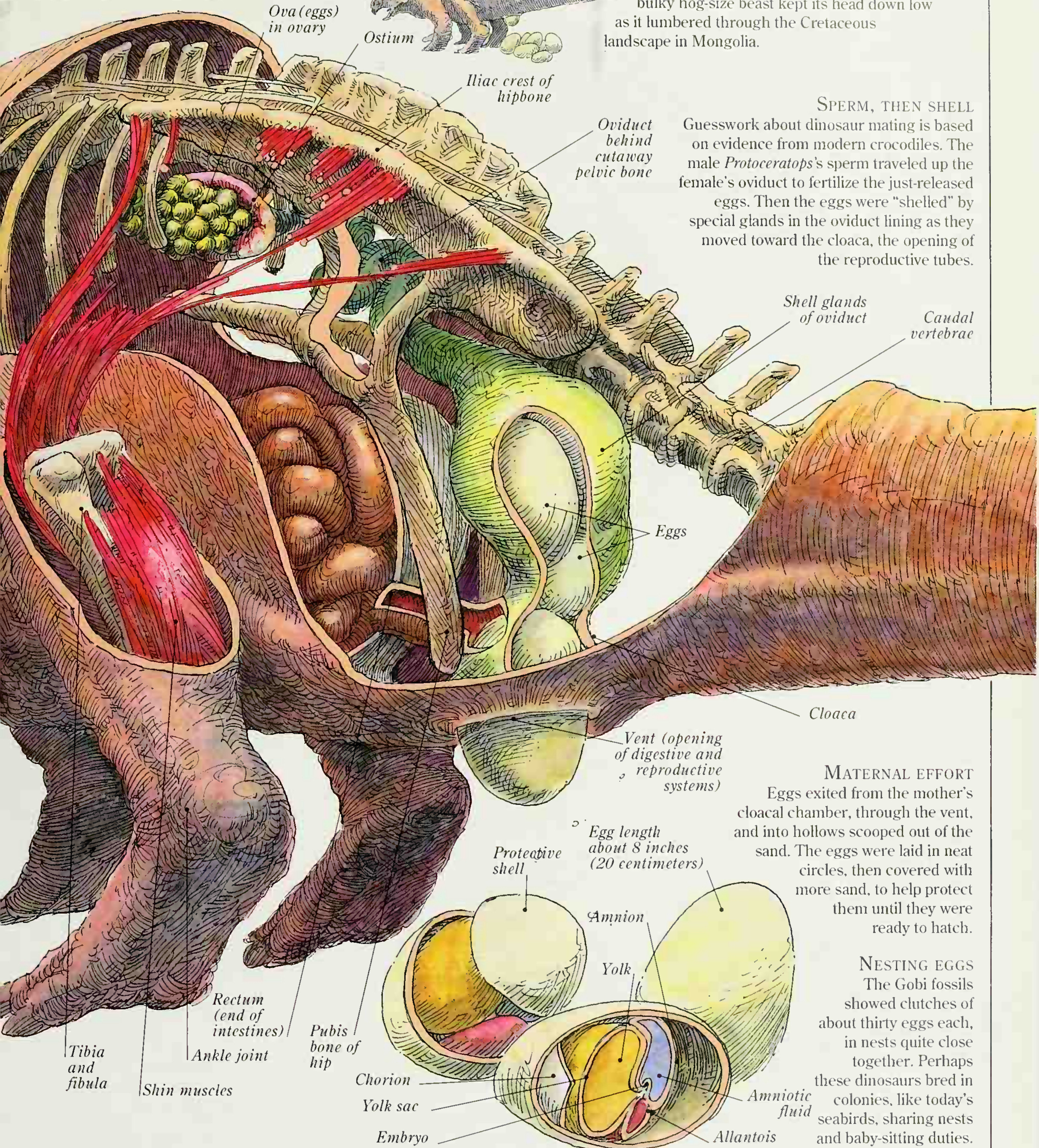
THE EGG MAKER

If dinosaurs were like present-day lizards and crocodiles, then two ovaries made eggs that passed through the funnel-shaped ostium and into the tubular oviduct.



PROTOCERATOPS

Almost 6 feet (2 meters) long and 397 pounds (180 kilograms) in weight, *Protoceratops* would have been nearly hip-high to a human. This bulky hog-size beast kept its head down low as it lumbered through the Cretaceous landscape in Mongolia.



SPERM, THEN SHELL

Guesswork about dinosaur mating is based on evidence from modern crocodiles. The male *Protoceratops*'s sperm traveled up the female's oviduct to fertilize the just-released eggs. Then the eggs were "shelled" by special glands in the oviduct lining as they moved toward the cloaca, the opening of the reproductive tubes.

MATERNAL EFFORT

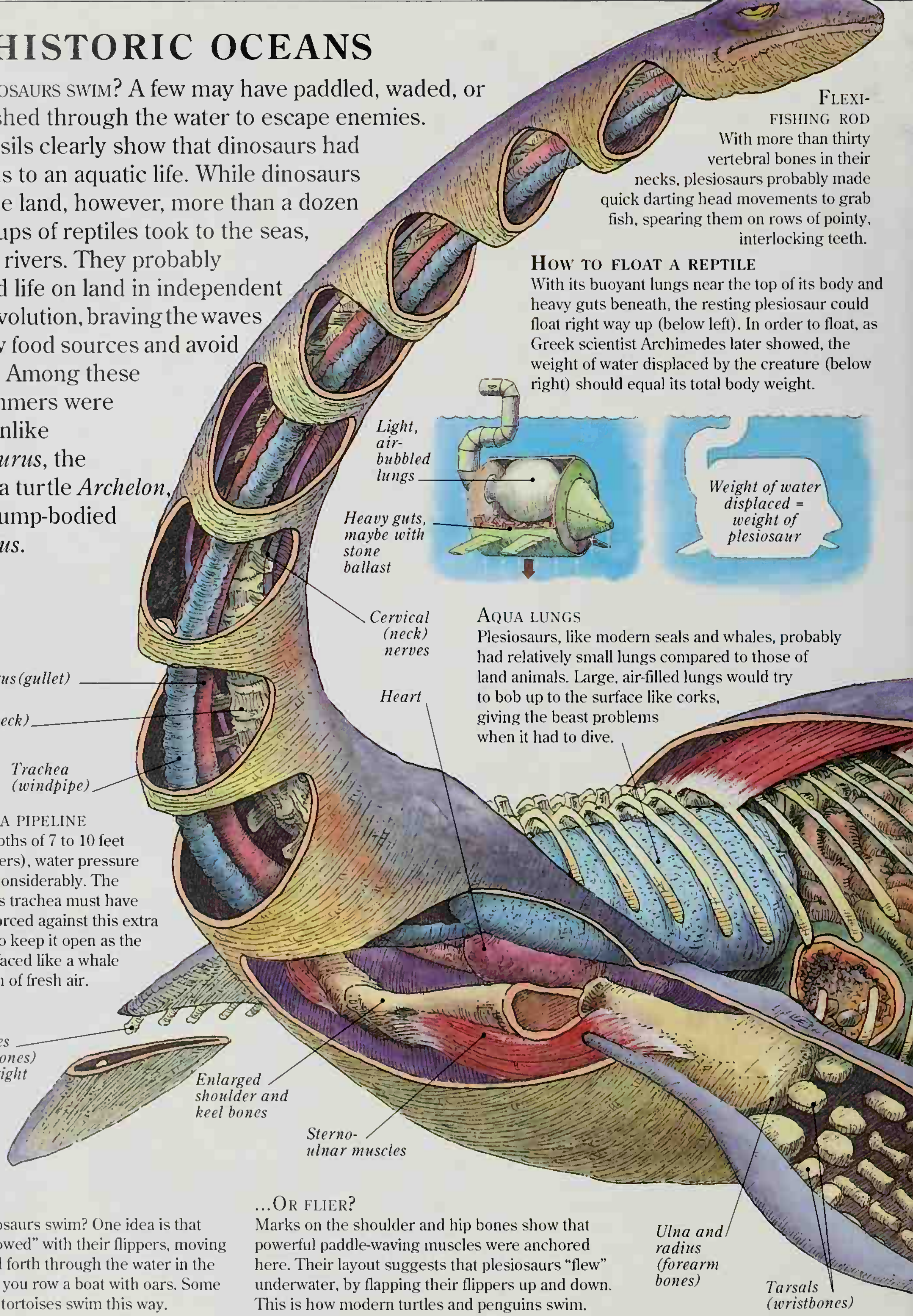
Eggs exited from the mother's cloacal chamber, through the vent, and into hollows scooped out of the sand. The eggs were laid in neat circles, then covered with more sand, to help protect them until they were ready to hatch.

NESTING EGGS

The Gobi fossils showed clutches of about thirty eggs each, in nests quite close together. Perhaps these dinosaurs bred in colonies, like today's seabirds, sharing nests and baby-sitting duties.

Prehistoric oceans

Could dinosaurs swim? A few may have paddled, waded, or even thrashed through the water to escape enemies. But no fossils clearly show that dinosaurs had adaptations to an aquatic life. While dinosaurs roamed the land, however, more than a dozen major groups of reptiles took to the seas, lakes, and rivers. They probably abandoned life on land in independent bursts of evolution, braving the waves to find new food sources and avoid predators. Among these scaly swimmers were the dolphinlike *Ichythyosaurus*, the ancient sea turtle *Archelon*, and the plump-bodied *Plesiosaurus*.



Flexi-fishing rod

With more than thirty vertebral bones in their necks, plesiosaurs probably made quick darting head movements to grab fish, spearing them on rows of pointy, interlocking teeth.

How to float a reptile

With its buoyant lungs near the top of its body and heavy guts beneath, the resting plesiosaur could float right way up (below left). In order to float, as Greek scientist Archimedes later showed, the weight of water displaced by the creature (below right) should equal its total body weight.

Aqua lungs

Plesiosaurs, like modern seals and whales, probably had relatively small lungs compared to those of land animals. Large, air-filled lungs would try to bob up to the surface like corks, giving the beast problems when it had to dive.

Undersea pipeline

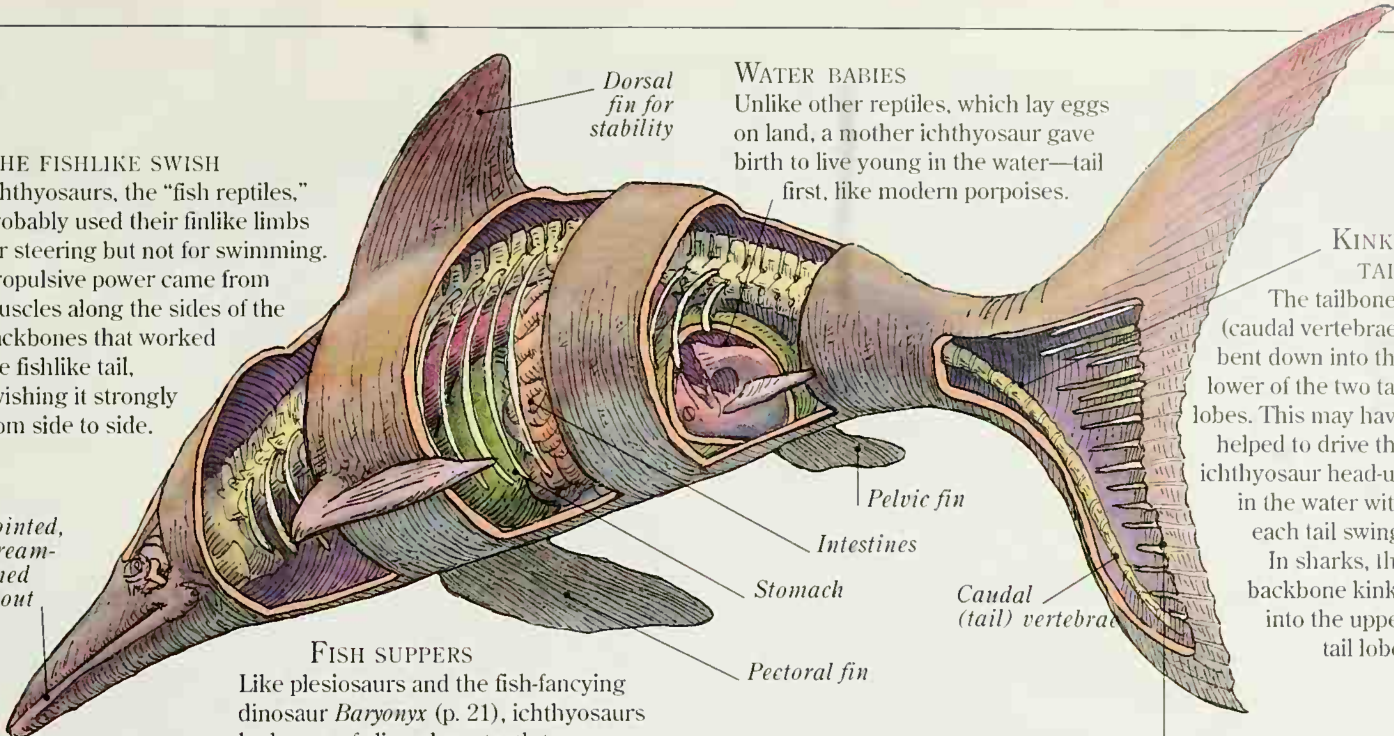
Even at depths of 7 to 10 feet (2 to 3 meters), water pressure increases considerably. The plesiosaur's trachea must have been reinforced against this extra pressure, to keep it open as the reptile surfaced like a whale for a breath of fresh air.

Rower...

How did plesiosaurs swim? One idea is that plesiosaurs "rowed" with their flippers, moving them back and forth through the water in the same way that you row a boat with oars. Some mammals and tortoises swim this way.

...Or flier?

Marks on the shoulder and hip bones show that powerful paddle-waving muscles were anchored here. Their layout suggests that plesiosaurs "flew" underwater, by flapping their flippers up and down. This is how modern turtles and penguins swim.



THE FISHLIKE SWISH
Ichthyosaurs, the "fish reptiles," probably used their finlike limbs for steering but not for swimming. Propulsive power came from muscles along the sides of the backbones that worked the fishlike tail, swishing it strongly from side to side.

WATER BABIES
Unlike other reptiles, which lay eggs on land, a mother ichthyosaur gave birth to live young in the water—tail first, like modern porpoises.

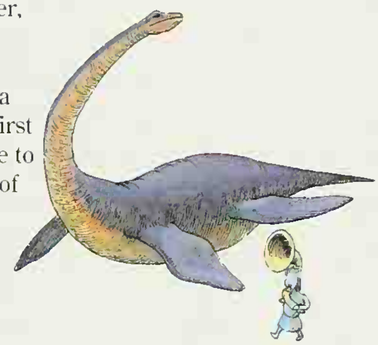
KINKY TAIL
The tailbones (caudal vertebrae) bent down into the lower of the two tail lobes. This may have helped to drive the ichthyosaur head-up in the water with each tail swing. In sharks, the backbone kinks into the upper tail lobe.

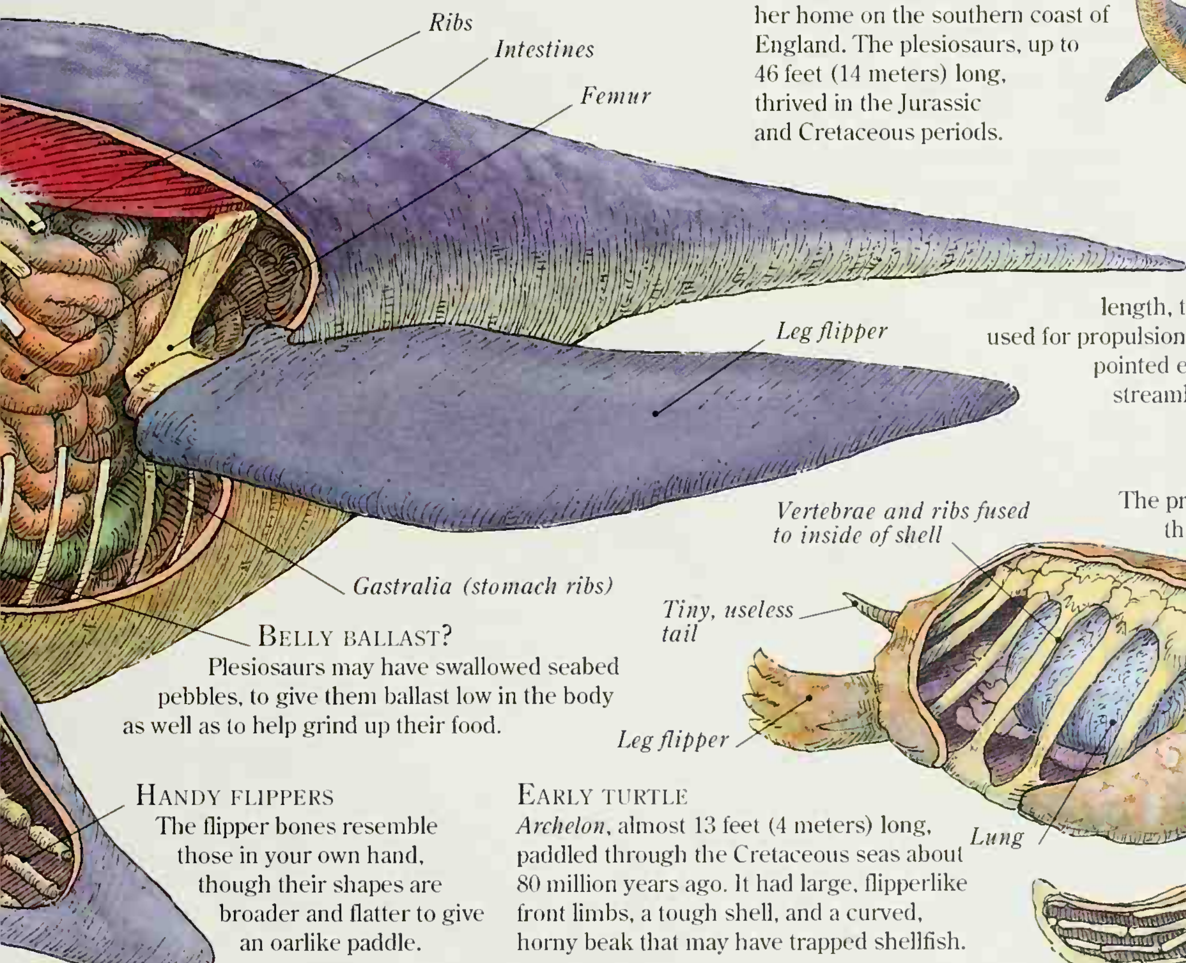
FISH SUPPERS
Like plesiosaurs and the fish-fancying dinosaur *Baryonyx* (p. 21), ichthyosaurs had rows of slim, sharp teeth to grasp their slippery, wriggling prey.

CONVERGENT EVOLUTION
Sharks, other fast fish, dolphins, and ichthyosaurs have remarkably similar overall shapes, even though they are quite different inside. They are streamlined to slip through the water as speedily as possible. This outer similarity is termed convergent evolution.

PLESIOSAURUS

The first professional fossil hunter, Mary Anning, found not only the earliest known remains of an ichthyosaur, but also uncovered a nearly complete skeleton of the first *Plesiosaurus* ("near reptile") close to her home on the southern coast of England. The plesiosaurs, up to 46 feet (14 meters) long, thrived in the Jurassic and Cretaceous periods.

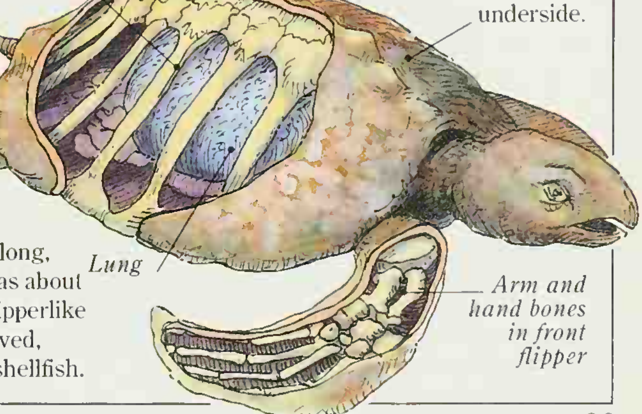




TAILING OFF
The typical plesiosaur tail was of medium length, tapering, and stiff. It was not used for propulsion, but was simply a smoothly pointed end to the body, to help with streamlining in the high-resistance aquatic environment.

DOUBLE PROTECTION
The protective bony shell is called the carapace on the back, and the plastron on the underside.

BELLY BALLAST?
Plesiosaurs may have swallowed seabed pebbles, to give them ballast low in the body as well as to help grind up their food.

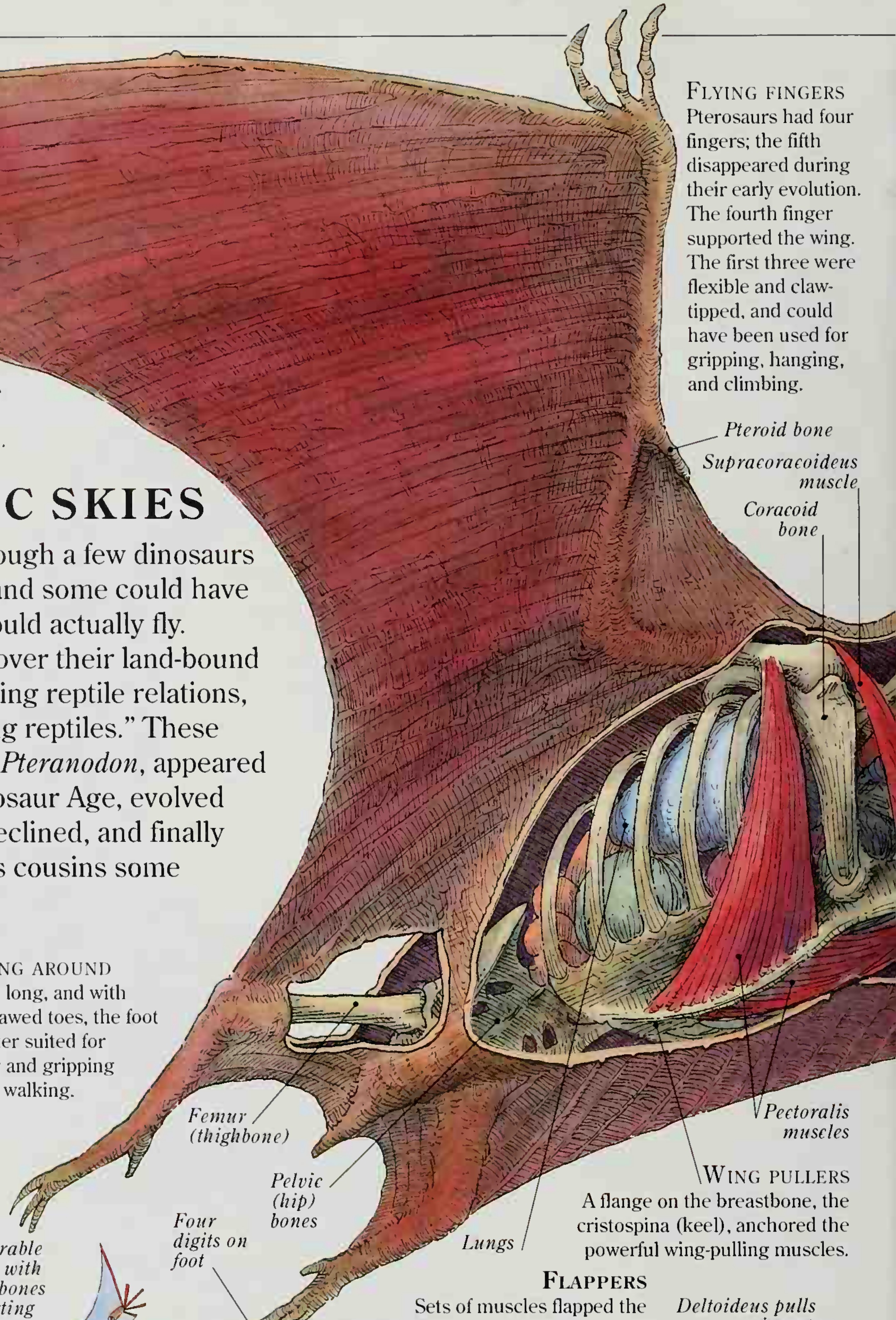


HANDY FLIPPERS
The flipper bones resemble those in your own hand, though their shapes are broader and flatter to give an oarlike paddle.

EARLY TURTLE
Archelon, almost 13 feet (4 meters) long, paddled through the Cretaceous seas about 80 million years ago. It had large, flipperlike front limbs, a tough shell, and a curved, horny beak that may have trapped shellfish.

Prehistoric skies

COULD DINOSAURS FLY? Although a few dinosaurs were undoubtedly nimble, and some could have jumped and leaped, none could actually fly. Soaring through the skies, over their land-bound dinosaur cousins and seagoing reptile relations, were the pterosaurs or "wing reptiles." These featherless fliers, including *Pteranodon*, appeared at the beginning of the Dinosaur Age, evolved and diversified, gradually declined, and finally died out with their flightless cousins some sixty-five million years ago.



Wing finger

Four incredibly long fouth-finger bones supported the wing. Another small bone near the claw, the pteroid, adjusted the shape of the wing to control flight speed.

Flying fingers

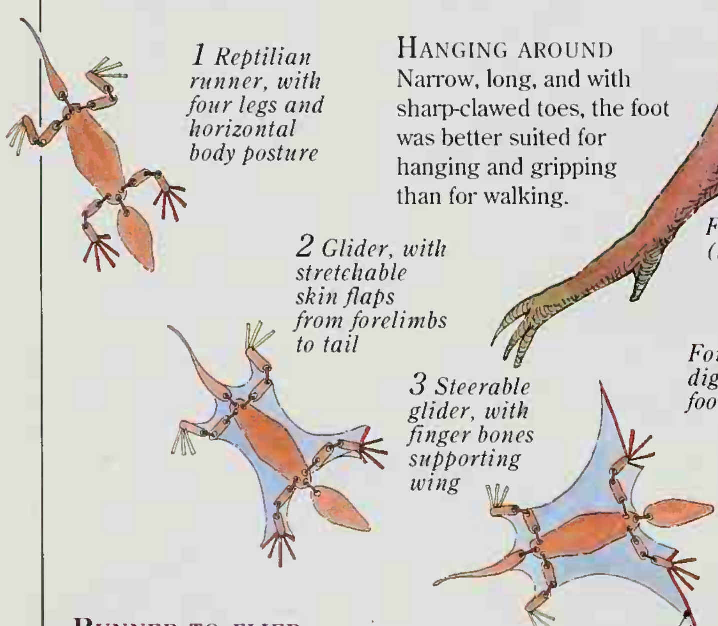
Pterosaurs had four fingers; the fifth disappeared during their early evolution. The fourth finger supported the wing. The first three were flexible and claw-tipped, and could have been used for gripping, hanging, and climbing.

Hanging around

Narrow, long, and with sharp-clawed toes, the foot was better suited for hanging and gripping than for walking.

Wing pullers

A flange on the breastbone, the cristospina (keel), anchored the powerful wing-pulling muscles.

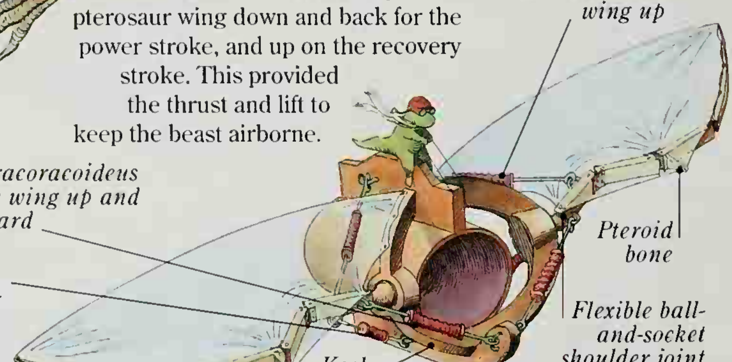


Runner to flier

This sequence shows how pterosaurs may have evolved from four-legged reptiles, more than 220 million years ago. In the intermediate stages, the parachutelike skin flaps would be useful for leaping and gliding away from enemies, as in today's flying squirrels.

Flappers

Sets of muscles flapped the pterosaur wing down and back for the power stroke, and up on the recovery stroke. This provided the thrust and lift to keep the beast airborne.

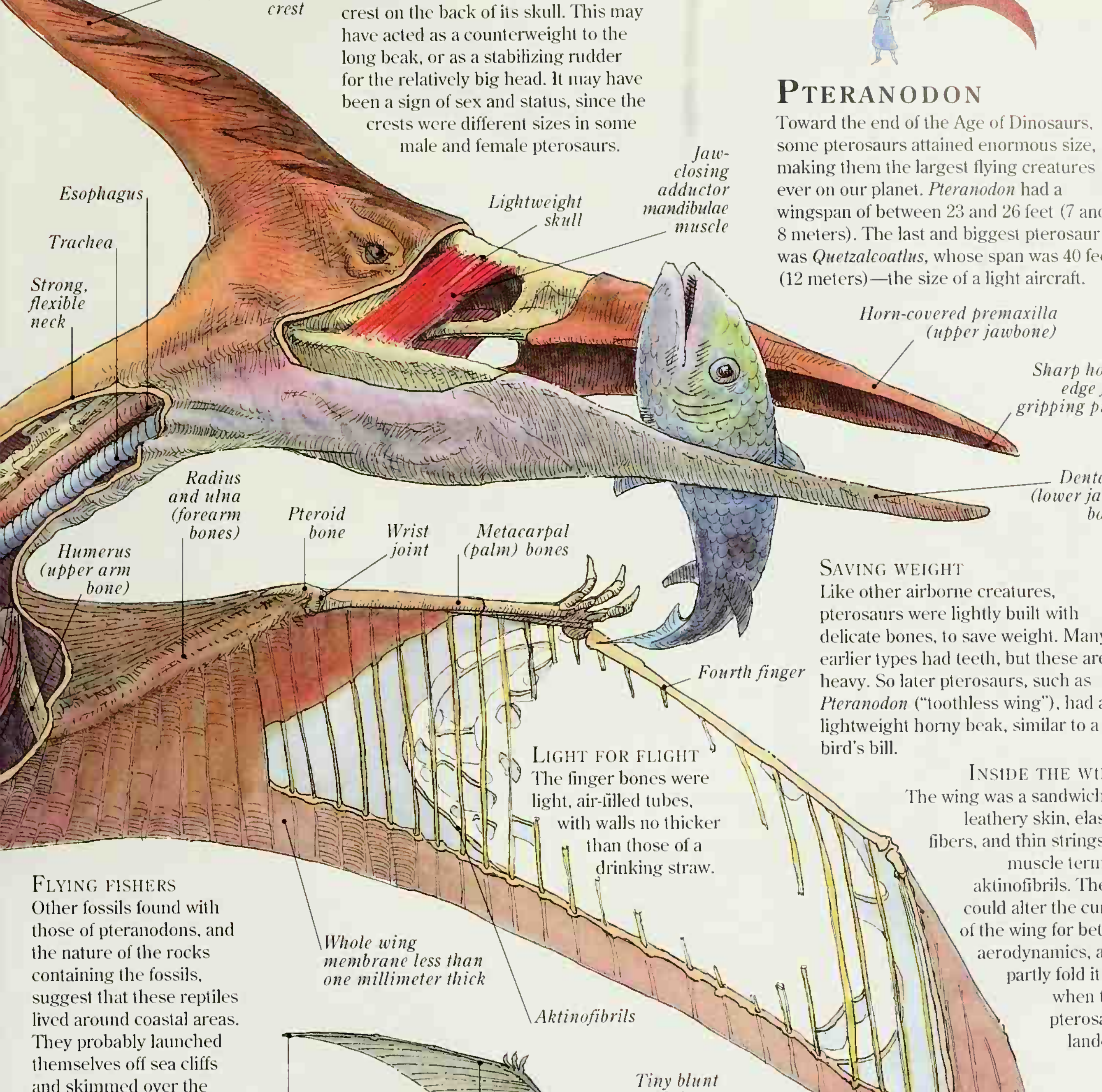


Pteranodon

Toward the end of the Age of Dinosaurs, some pterosaurs attained enormous size, making them the largest flying creatures ever on our planet. *Pteranodon* had a wingspan of between 23 and 26 feet (7 and 8 meters). The last and biggest pterosaur was *Quetzalcoatlus*, whose span was 40 feet (12 meters)—the size of a light aircraft.

Beak-balancer?

Pteranodon had a large, bony, pointed crest on the back of its skull. This may have acted as a counterweight to the long beak, or as a stabilizing rudder for the relatively big head. It may have been a sign of sex and status, since the crests were different sizes in some male and female pterosaurs.



Saving weight

Like other airborne creatures, pterosaurs were lightly built with delicate bones, to save weight. Many earlier types had teeth, but these are heavy. So later pterosaurs, such as *Pteranodon* ("toothless wing"), had a lightweight horny beak, similar to a bird's bill.

Light for flight

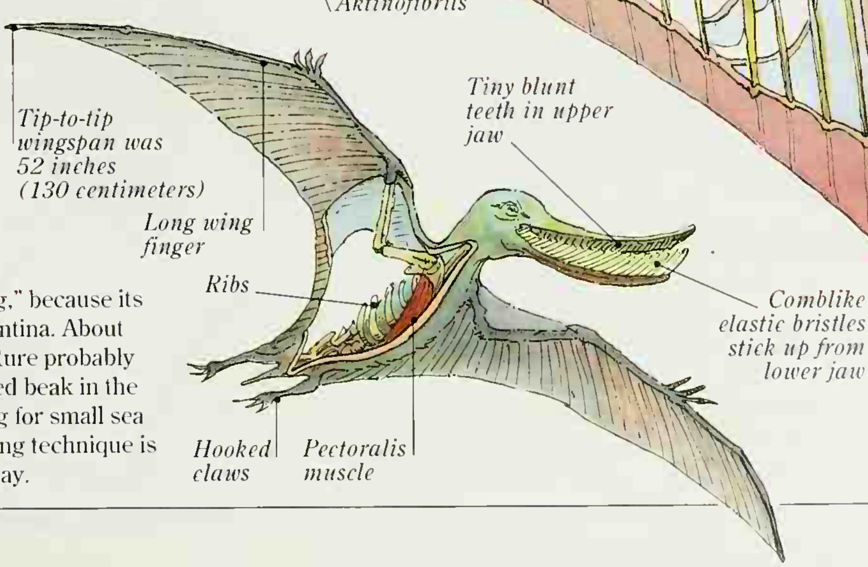
The finger bones were light, air-filled tubes, with walls no thicker than those of a drinking straw.

Inside the wing

The wing was a sandwich of leathery skin, elastic fibers, and thin strings of muscle termed aktinofibrils. These could alter the curve of the wing for better aerodynamics, and partly fold it up when the pterosaur landed.

Flying fishers

Other fossils found with those of pteranodons, and the nature of the rocks containing the fossils, suggest that these reptiles lived around coastal areas. They probably launched themselves off sea cliffs and skimmed over the waves, snatching fish in their beaks.

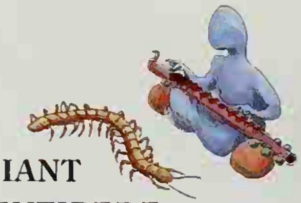


Fringed filters

Pterodaustro means "south wing," because its fossils were discovered in Argentina. About 140 million years ago, this creature probably dabbled its extraordinary fringed beak in the shallow shore waters, searching for small sea creatures. The same filter-feeding technique is employed by baleen whales today.

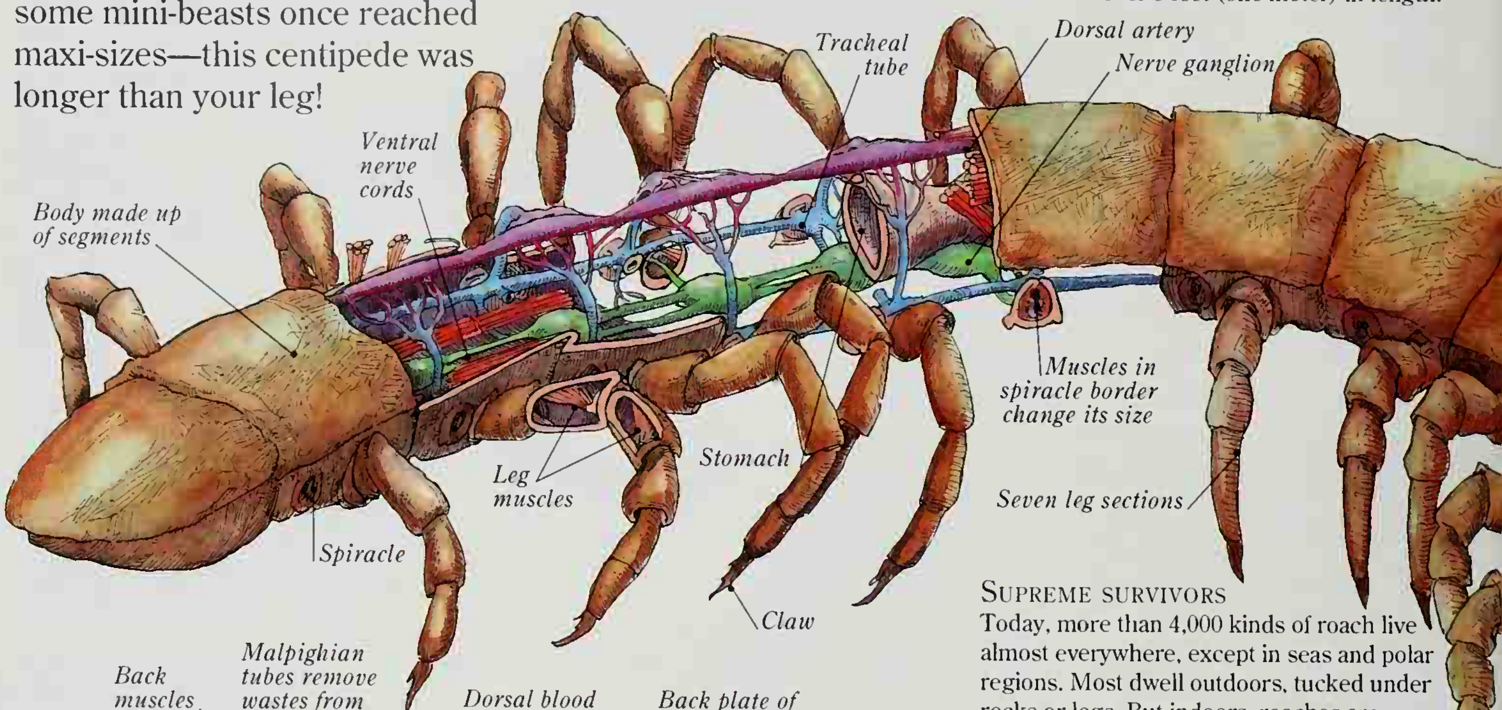
Creepy-crawlies

What's older than a dinosaur? Long before any backboned creatures—whether amphibian or reptile—set foot on land, invertebrates (animals without backbones) crept across the Earth. Among the first were arthropods, animals with a hard outer body casing and jointed legs. They included centipedes, millipedes, mites, ticks, scorpions, and insects. With a 400-million-year history, land arthropods far outlived the dinosaurs, and still survive in incredible numbers. Today these small scurriers are sometimes called "mini-beasts." But some mini-beasts once reached maxi-sizes—this centipede was longer than your leg!



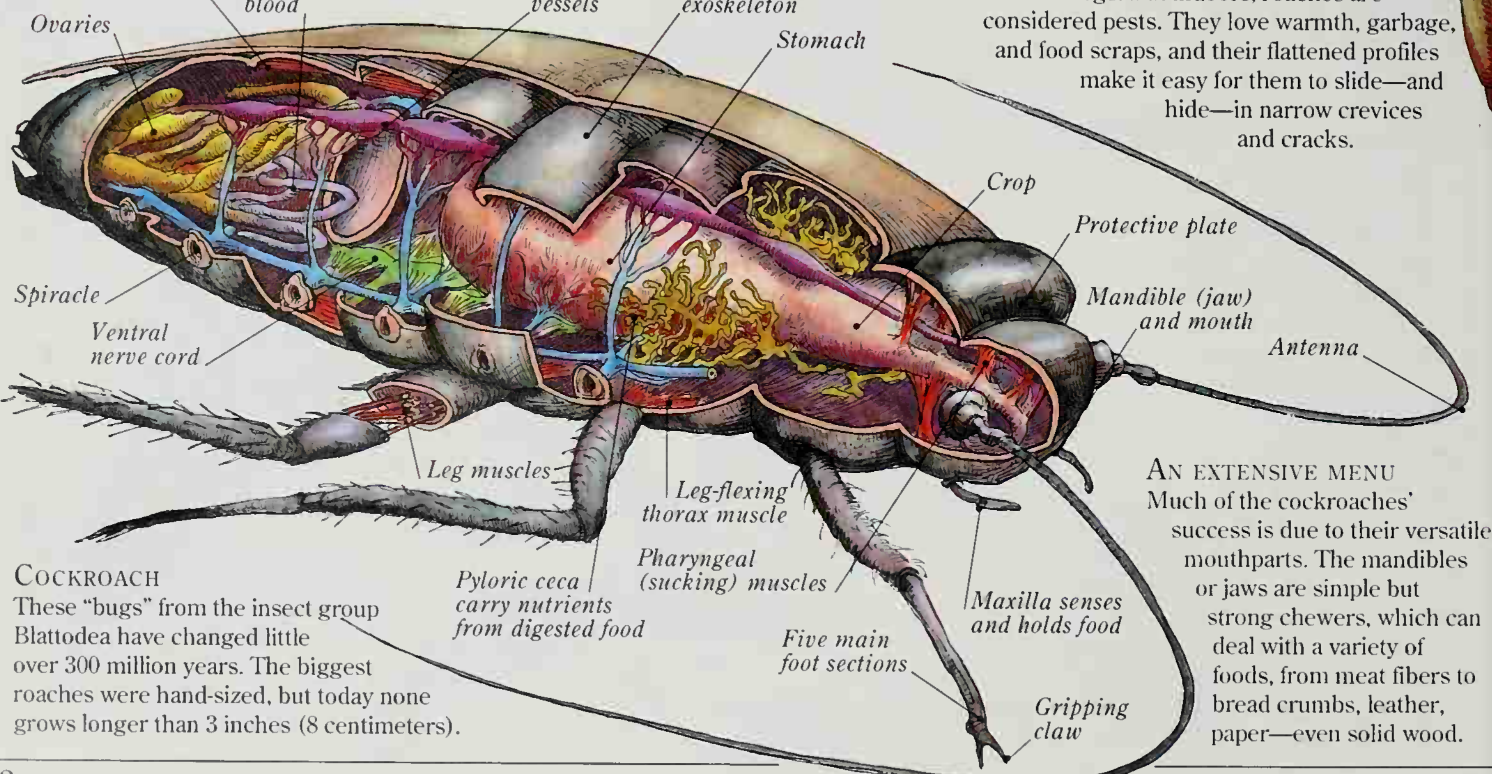
Giant centipede

Centipedes make up the group Chilopoda. They first crawled the land 250 million years ago. Today these creatures grow to about 10 inches (25 centimeters) long, but their ancient cousins reached over 3 feet (one meter) in length.



Supreme survivors

Today, more than 4,000 kinds of roach live almost everywhere, except in seas and polar regions. Most dwell outdoors, tucked under rocks or logs. But indoors, roaches are considered pests. They love warmth, garbage, and food scraps, and their flattened profiles make it easy for them to slide—and hide—in narrow crevices and cracks.



Cockroach

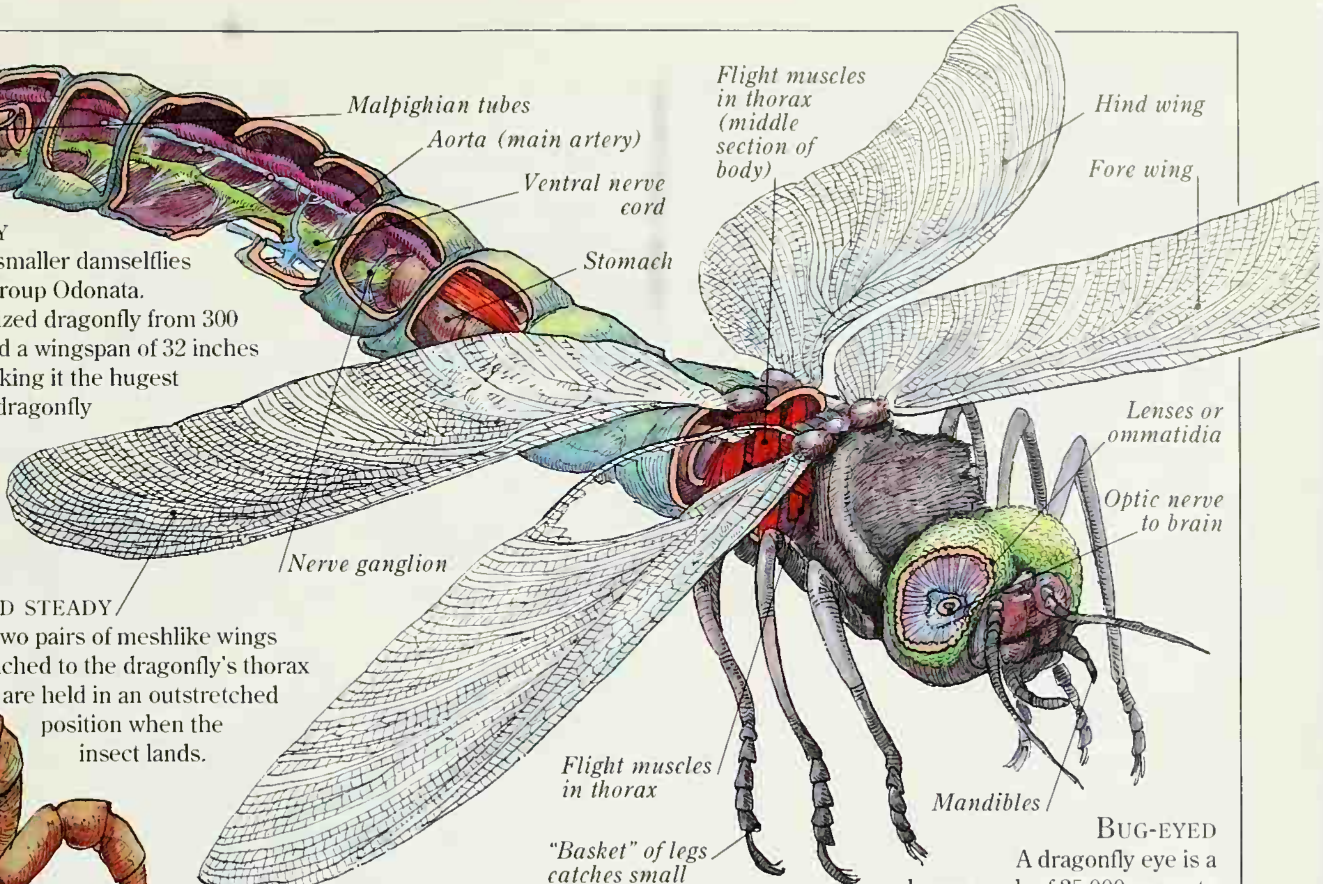
These "bugs" from the insect group Blattodea have changed little over 300 million years. The biggest roaches were hand-sized, but today none grows longer than 3 inches (8 centimeters).

An extensive menu

Much of the cockroaches' success is due to their versatile mouthparts. The mandibles or jaws are simple but strong chewers, which can deal with a variety of foods, from meat fibers to bread crumbs, leather, paper—even solid wood.

Giant dragonfly

Dragonflies and the smaller damselflies make up the insect group Odonata. *Meganeura*, a crow-sized dragonfly from 300 million years ago, had a wingspan of 32 inches (80 centimeters), making it the hugest insect ever. Today's dragonfly wingspans are only 8 inches (20 centimeters).



Hold steady

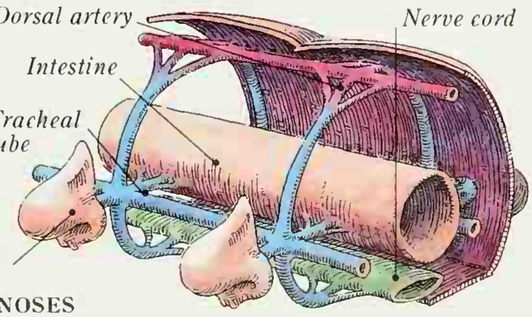
The two pairs of meshlike wings attached to the dragonfly's thorax are held in an outstretched position when the insect lands.

Bug-eyed

A dragonfly eye is a honeycomb of 25,000 separate lenses, known as ommatidia. Each focuses light rays to form an image of a small part of the scene. These images are somehow combined in the insect's brain.

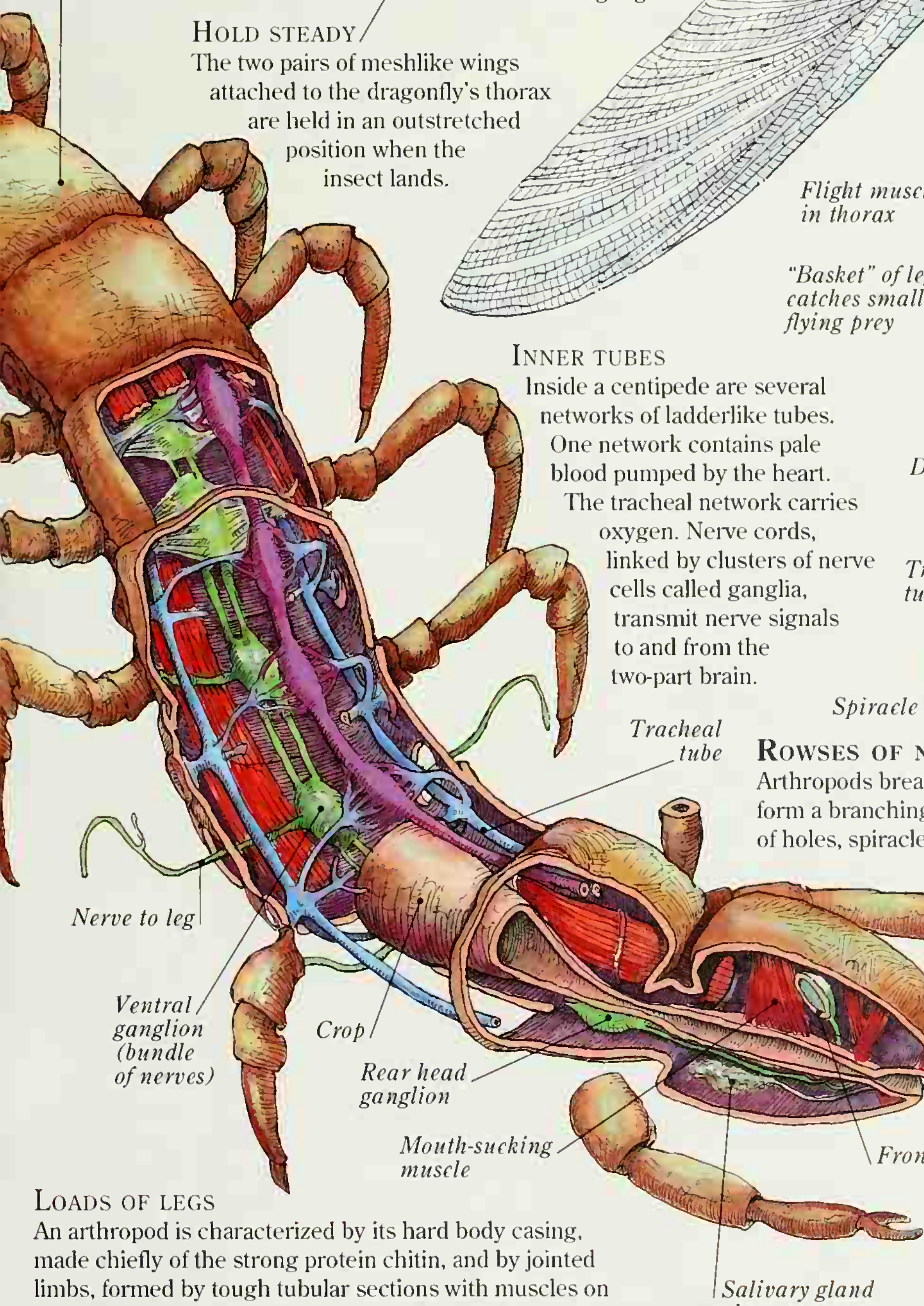
Inner tubes

Inside a centipede are several networks of ladderlike tubes. One network contains pale blood pumped by the heart. The tracheal network carries oxygen. Nerve cords, linked by clusters of nerve cells called ganglia, transmit nerve signals to and from the two-part brain.



Rowses of noses

Arthropods breathe by a system of air tubes known as trachea, that form a branching network through the body. The tubes open at rows of holes, spiracles, along the creature's body. Their microscopic branches carry oxygen directly to the muscles, nerves, guts, and body fluids. Body and muscle movements keep the air on the move.



Loads of legs

An arthropod is characterized by its hard body casing, made chiefly of the strong protein chitin, and by jointed limbs, formed by tough tubular sections with muscles on the inside. Centipede means "a hundred legs," but only a few of the 3,000 living species have exactly this number.

Poisonous bite

Centipedes are the terrors of the leaf litter. They usually hide during the day, then chase their victims—worms, snails, wood lice, and insects—at night. The centipede seizes its struggling meal in its first pair of legs, which resemble massive fangs, and delivers a paralyzing poisonous bite.

Fur and feather

Fur means mammal, and feathers mean bird. But it's not always so clear-cut. Extinct animals must be classified on the basis of their fossil remains. From the details of its teeth, jaw, and ear bones, we know that *Probelesodon* shown here is technically a reptile. Yet its fossils imply that it was so far along the road to becoming a mammal, it had fur and whiskers. The famous flying *Archaeopteryx* also had reptilian features, such as teeth, wing claws, and a chain of tailbones, which modern birds lack. But its fossilized feathers mark it out as the earliest known bird.

Archaeopteryx

Only six fossil specimens of the chicken-size "ancient wing" have been found, all from southeast Germany. Feathers aside, they are so similar to reptiles that some were first identified as small pterosaurs, or dinosaurs such as *Compsognathus*. The remains are 150 million years old.

Fortunate preservation

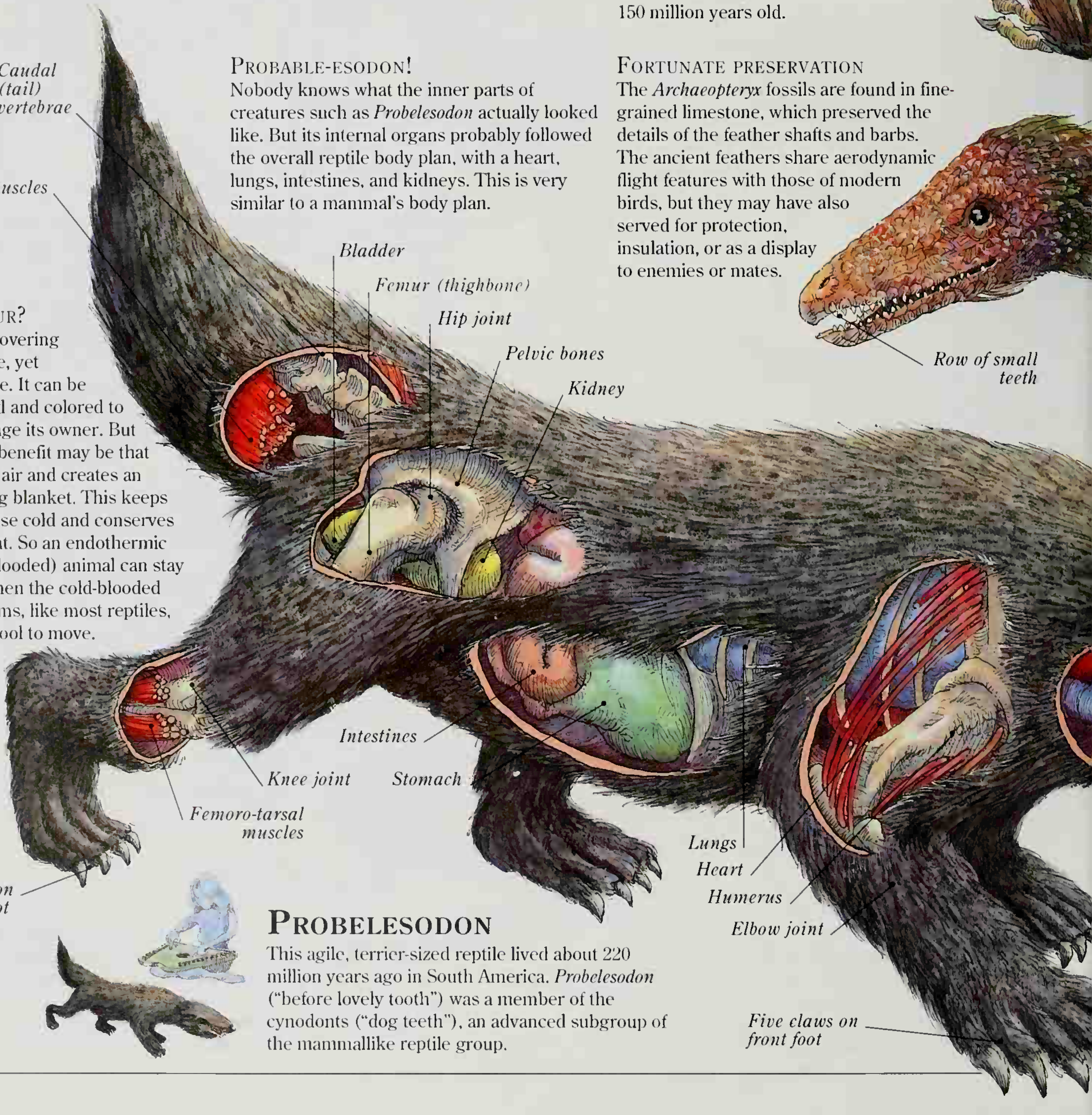
The *Archaeopteryx* fossils are found in fine-grained limestone, which preserved the details of the feather shafts and barbs. The ancient feathers share aerodynamic flight features with those of modern birds, but they may have also served for protection, insulation, or as a display to enemies or mates.

Probable-esodon!

Nobody knows what the inner parts of creatures such as *Probelesodon* actually looked like. But its internal organs probably followed the overall reptile body plan, with a heart, lungs, intestines, and kidneys. This is very similar to a mammal's body plan.

Why fur?

A furry covering is flexible, yet protective. It can be patterned and colored to camouflage its owner. But its main benefit may be that fur traps air and creates an insulating blanket. This keeps out intense cold and conserves body heat. So an endothermic (warm-blooded) animal can stay active when the cold-blooded ectotherms, like most reptiles, are too cool to move.

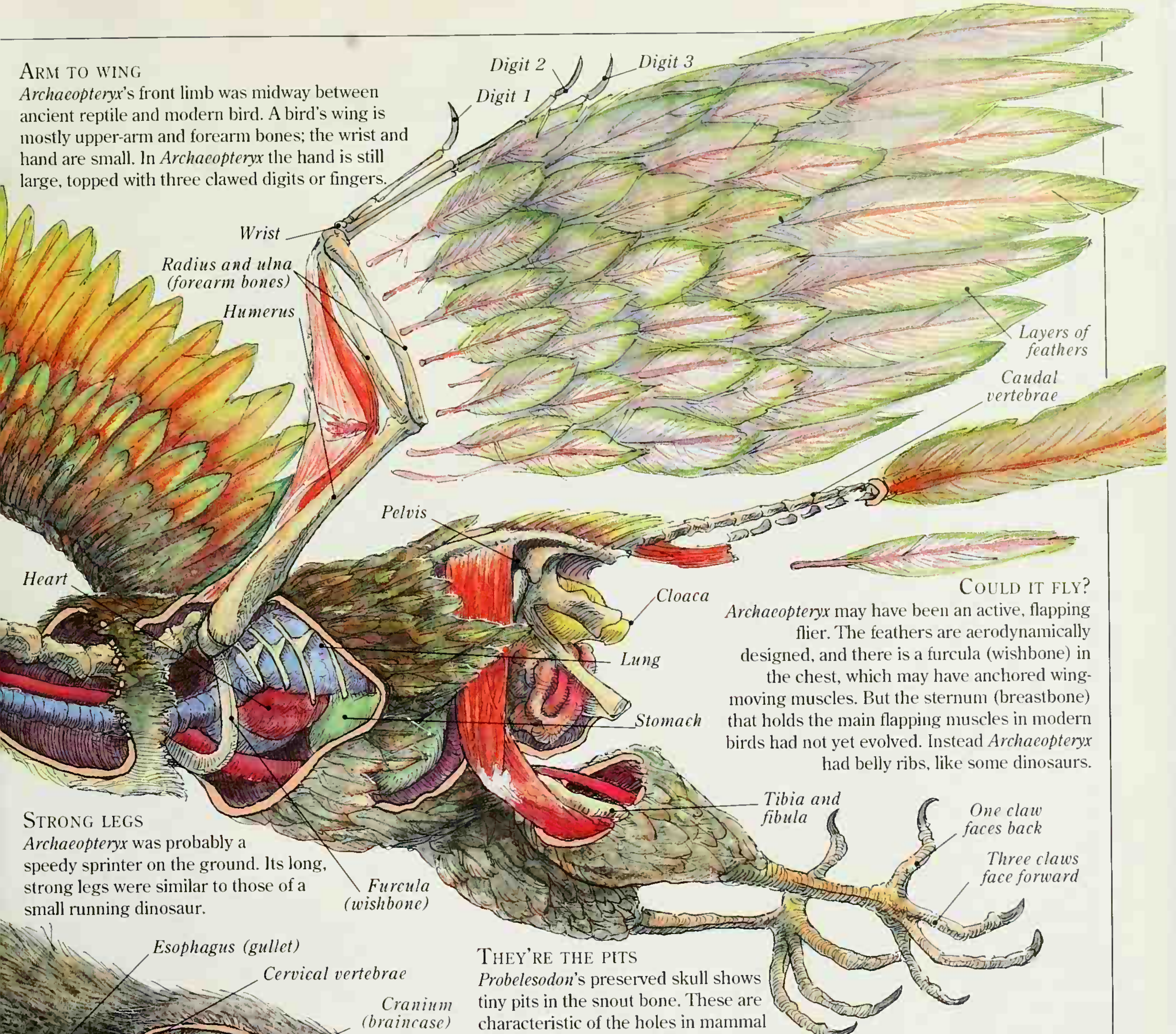


Probelesodon

This agile, terrier-sized reptile lived about 220 million years ago in South America. *Probelesodon* ("before lovely tooth") was a member of the cynodonts ("dog teeth"), an advanced subgroup of the mammallike reptile group.

Arm to wing

Archaeopteryx's front limb was midway between ancient reptile and modern bird. A bird's wing is mostly upper-arm and forearm bones; the wrist and hand are small. In *Archaeopteryx* the hand is still large, topped with three clawed digits or fingers.



Could it fly?

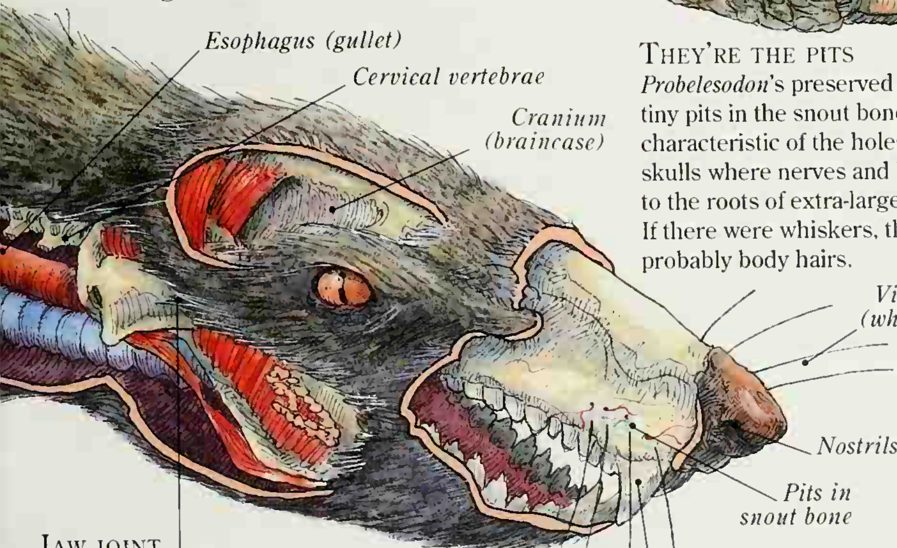
Archaeopteryx may have been an active, flapping flier. The feathers are aerodynamically designed, and there is a furcula (wishbone) in the chest, which may have anchored wing-moving muscles. But the sternum (breastbone) that holds the main flapping muscles in modern birds had not yet evolved. Instead *Archaeopteryx* had belly ribs, like some dinosaurs.

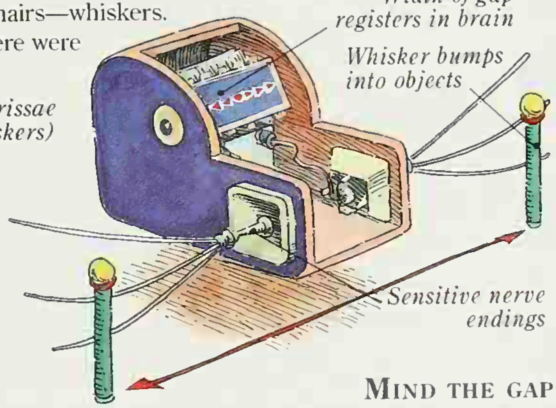
Strong legs

Archaeopteryx was probably a speedy sprinter on the ground. Its long, strong legs were similar to those of a small running dinosaur.

They're the pits

Probelesodon's preserved skull shows tiny pits in the snout bone. These are characteristic of the holes in mammal skulls where nerves and blood vessels pass to the roots of extra-large hairs—whiskers. If there were whiskers, there were probably body hairs.





Jaw joint

A fossil jaw joint can tell you whether its owner was a reptile or a mammal. In reptiles, the articular bone of the lower jaw hinged to the quadrate bone of the skull. In mammals these two bones became part of the sound-conducting chain of bones in the inner ear.

Mind the gap

A mammal's whiskers have movement-sensitive nerve endings wrapped around their roots. As a whisker tilts, the nerve endings signal to the brain, which forms a touch-picture of obstructions and gaps ahead. So the mammal can feel its way along even in darkness. Perhaps *Probelesodon* had the same system.

The first reptiles
Hard on the heels of the amphibians came reptiles, around 330 million years ago. Compared with the amphibians' moist skin and jelly-covered eggs (spawn), the reptiles' scaly skin and shelled eggs helped survival on dry land. Soon reptiles were everywhere.

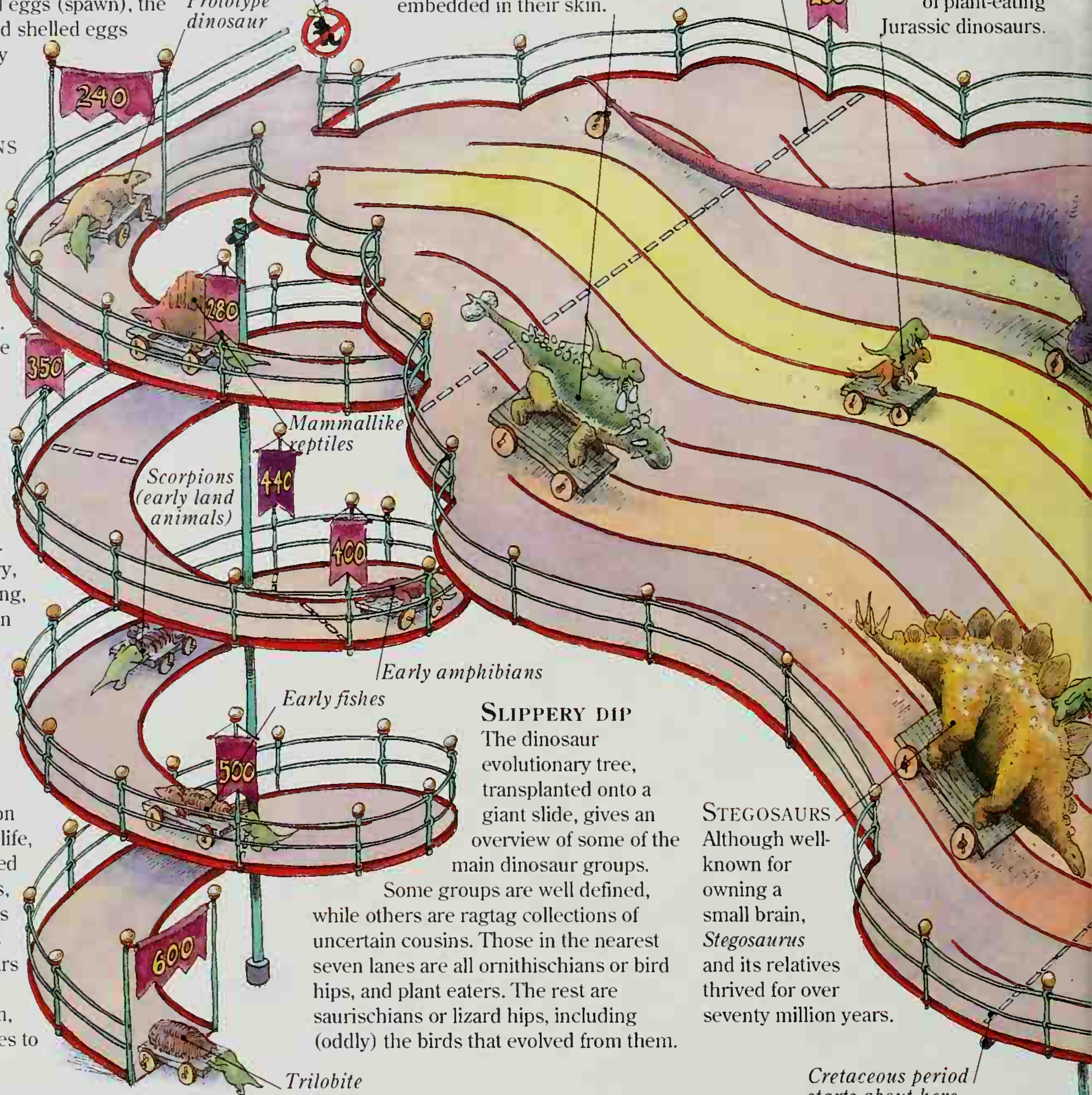
Age of amphibians
Some fishes were not content to suffocate in drying lakes. By 350 million years ago, they had developed lungs and their fins had become four legs. They crawled from the water—the first amphibians.

Age of fishes
By 450 million years ago, backboned fishes swam among the shelled creatures. At first they had heavy, bony armor and sieving, sucking mouths. Then they evolved proper fins, biting jaws, and lightweight scales.

Age of invertebrates
After nearly two billion years of microscopic life, followed by soft-bodied jellyfishes and worms, nature invented shells and other body cases about 600 million years ago. There was an explosion of evolution, from tanklike trilobites to hard-cased mollusks.

Ankylosaurs
Ankylosaurs ("fused reptiles"), including *Hylaeosaurus*, were named for the fused bones embedded in their skin.

Heterodontosaurs
Small as a dog, *Heterodontosaurus* was in a little group of plant-eating Jurassic dinosaurs.



Slippery dip
The dinosaur evolutionary tree, transplanted onto a giant slide, gives an overview of some of the main dinosaur groups. Some groups are well defined, while others are ragtag collections of uncertain cousins. Those in the nearest seven lanes are all ornithischians or bird hips, and plant eaters. The rest are saurischians or lizard hips, including (oddly) the birds that evolved from them.

Stegosaurs
Although well-known for owning a small brain, *Stegosaurus* and its relatives thrived for over seventy million years.

The slide to extinction

Life is a slippery slide toward death. A cat may live ten years, a giant tortoise one hundred years, and a huge tree 1,000 years. On the vastly longer time scale of Earth history, whole groups of living things evolve, flourish, and die. Humans have been around for scarcely two million years. Dinosaurs outdid us—nearly eighty times longer. More than 1,000 kinds or species of dinosaur came and went during the Mesozoic Era. Despite their numbers, variety, and adaptability, they could not cope with some type of change at the end of the Cretaceous period. Even the ultra-successful dinosaurs succumbed in the end.

The dinosaur age
Prehistory is divided into time chunks known as eras, which are split into periods. Dinosaurs lived in the Mesozoic Era, from 64 million to around 240 million years ago. This comprised three periods: the Triassic (198 to 240 million years ago), when dinosaurs first appeared; the Jurassic (135 to 198 million years ago), heyday of the huge plant eaters; and the Cretaceous (64 to 135 million years ago), which closed with their extinction.

Diplodocid sauropods
Diplodocus and its relations were members of the sauropod group. One of them was *Apatosaurus*—formerly known by the (now extinct) name *Brontosaurus*.

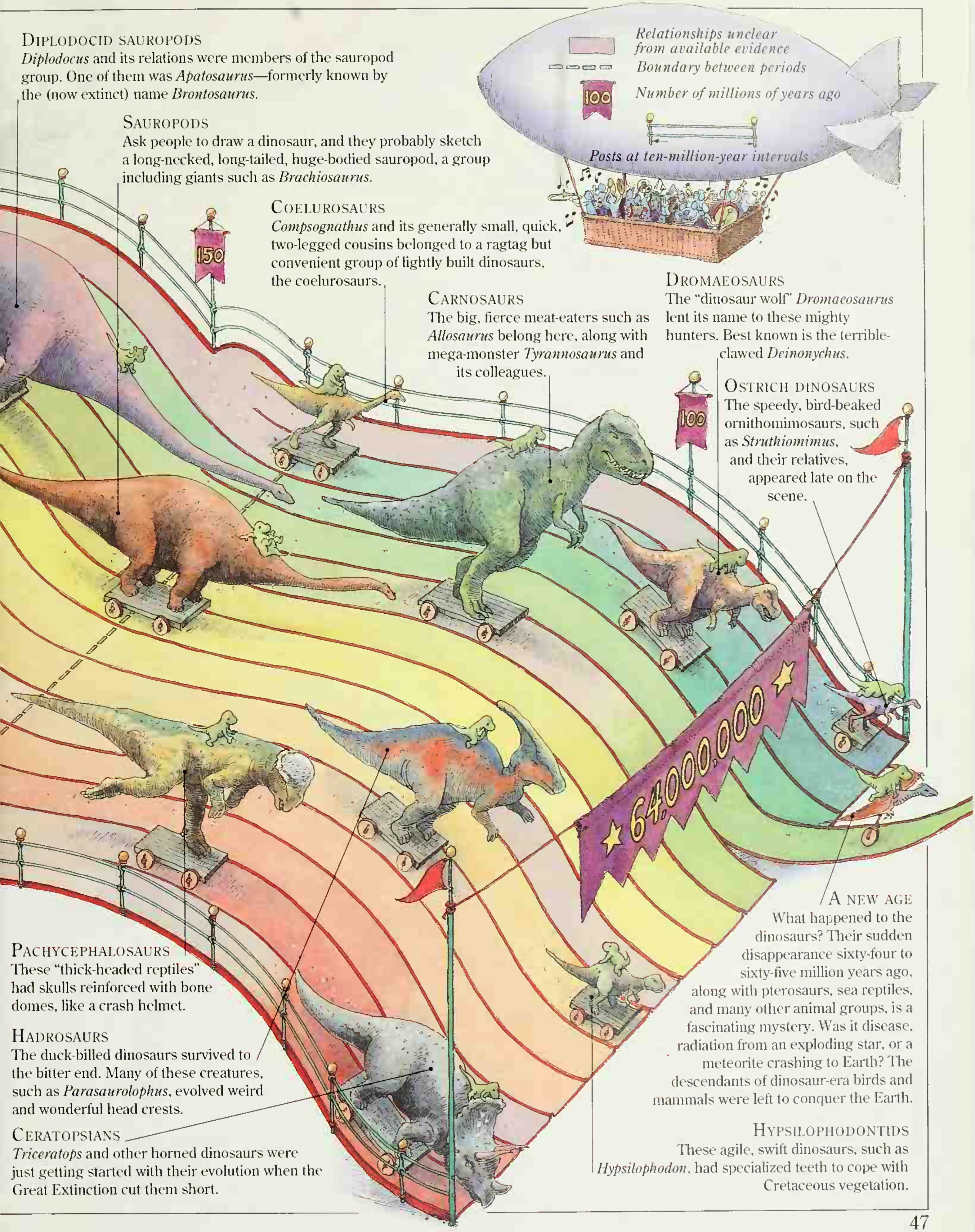
Sauropods
Ask people to draw a dinosaur, and they probably sketch a long-necked, long-tailed, huge-bodied sauropod, a group including giants such as *Brachiosaurus*.

Coelurosaurs
Compsognathus and its generally small, quick, two-legged cousins belonged to a ragtag but convenient group of lightly built dinosaurs, the coelurosaurs.

Carnosaurs
The big, fierce meat-eaters such as *Allosaurus* belong here, along with mega-monster *Tyrannosaurus* and its colleagues.

Dromaeosaurs
The "dinosaur wolf" *Dromaeosaurus* lent its name to these mighty hunters. Best known is the terrible-clawed *Deinonychus*.

Ostrich dinosaurs
The speedy, bird-beaked ornithomimosaurs, such as *Struthiomimus*, and their relatives, appeared late on the scene.



Pachycephalosaurs
These "thick-headed reptiles" had skulls reinforced with bone domes, like a crash helmet.

Hadrosaurs
The duck-billed dinosaurs survived to the bitter end. Many of these creatures, such as *Parasaurolophus*, evolved weird and wonderful head crests.

Ceratopsians
Triceratops and other horned dinosaurs were just getting started with their evolution when the Great Extinction cut them short.

A new age
What happened to the dinosaurs? Their sudden disappearance sixty-four to sixty-five million years ago, along with pterosaurs, sea reptiles, and many other animal groups, is a fascinating mystery. Was it disease, radiation from an exploding star, or a meteorite crashing to Earth? The descendants of dinosaur-era birds and mammals were left to conquer the Earth.

Hypsilophodontids
These agile, swift dinosaurs, such as *Hypsilophodon*, had specialized teeth to cope with Cretaceous vegetation.

INDEX

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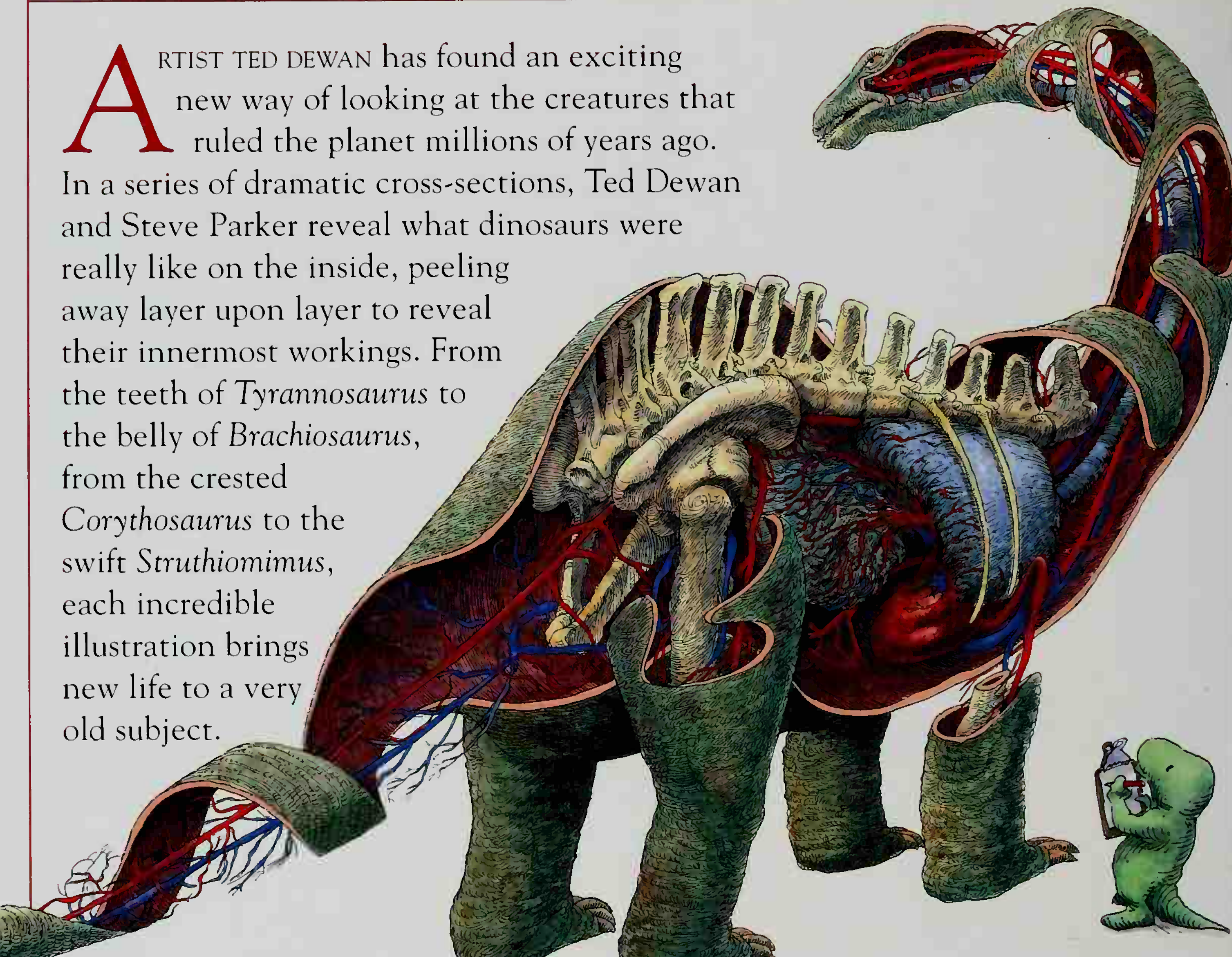
INSIDE DINOSAURS

AND OTHER PREHISTORIC CREATURES

ARTIST TED DEWAN has found an exciting new way of looking at the creatures that ruled the planet millions of years ago. In a series of dramatic cross-sections, Ted Dewan and Steve Parker reveal what dinosaurs were really like on the inside, peeling away layer upon layer to reveal their innermost workings. From the teeth of *Tyrannosaurus* to the belly of *Brachiosaurus*, from the crested *Corythosaurus* to the swift *Struthiomimus*, each incredible illustration brings new life to a very old subject.



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